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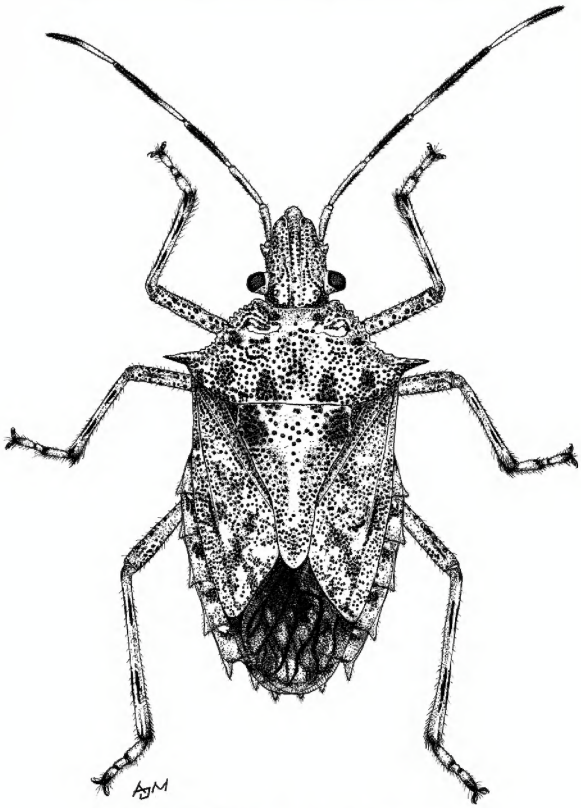

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Membership is open to anyone interested in Entomology. Meetings are normally held at the Ecosciences Precinct, Dutton Park, at 1.00 pm on the second Tuesday of March–June and August–December each year. Meetings are announced in the Society's News Bulletin which also contains reports of meetings, entomological notes, notices of other Society events and information on Members' activities. Enquiries relating to the Society should be sent to the Honorary Secretary, Entomological Society of Queensland, P.O. Box 537, Indooroopilly, Qld, 4068.

COVER

Bromocoris souefi (Distant, 1910) (Hemiptera: Pentatomidae) was described by British hemipterist, W.L. Distant, from a specimen collected at Cooktown in 1896 by W.H.D. Le Souëf after whom it is named. He was son of the Director of the Melbourne Zoo and collected it on an expedition to collect tree kangaroos for the zoo. It occurs in Indonesia, New Guinea and northern Australia. Its range in Australia has recently expanded southerly and it has been common in Brisbane since 2006. Females brood and vigorously guard their eggs and first instars on the undersides of leaves of many tree species. The illustration is ink on paper by ESQ member Dr Andrew Maynard who received his UQ PhD in 2020 on the invasion history and evolution of *Aedes albopictus* and *Aedes aegypti* in the Indo-Pacific. He works in Brisbane at the Dept. of Agriculture, Water and the Environment as a biosecurity entomologist with special interest in Hemiptera. *Bromocoris souefi* is routinely intercepted.

FIRST RECORD OF *ACRAEA TERPSICORE* (LINNAEUS, 1758) (LEPIDOPTERA: NYMPHALIDAE) FROM NEW SOUTH WALES, AUSTRALIA

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Abstract
The first record of *Acraea terpsicore* (Linnaeus) (Lepidoptera: Nymphalidae) in New South Wales is recorded from Coffs Harbour.

Keywords: Tawny Coster, Coffs Harbour, recent arrival.

Introduction
The Tawny Coster butterfly, *Acraea terpsicore*, is a relatively recent arrival to Australia (Sanderson *et al*. 2012; Braby *et al*. 2014; Franklin *et al*. 2017; Ham 2020), with the first specimens collected near Darwin in 2012 (Braby 2016). Later, Braby *et al*. (2014) predicted that the species would become widely distributed throughout tropical Queensland, but since then it has spread into sub-tropical and even semi-arid zones of Queensland (Ham 2020). On 1 November 2020, two

Fig. 1. *Acraea terpsicore* in flight at the Coffs Harbour marina car park.

specimens of this species were observed at Coffs Harbour, New South Wales with one of these recorded on video in flight. This constitutes the first record of this species in New South Wales.

Observations

One specimen was observed at 11 am flying slowly north against a strong prevailing wind in a carpark adjacent to the marina in Coffs Harbour, NSW. This specimen was observed for approximately 5 minutes, gaining only 20 m against the wind. As it was flying between 30 cm and 2 m above the ground, its flight was filmed using a mobile phone (still frame: Fig. 1). A second specimen was observed at around 1 pm, 1 km south of the marina, flying due north against the prevailing wind at a height of 1 m above the ground. The second location was a large, open park adjacent to the foreshore and beach at the Coffs Harbour Jetty. Both specimens were flying in a similar direction to many Caper White butterflies, *Belenois java teutonia* (Fabricius) (Lepidoptera: Pieridae) which also were migrating at the time.

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OBSERVATIONS ON THE NATURAL HISTORY OF THE PLATFORM-WEAVING SPIDERS, GENUS *CORASOIDES* BUTLER (ARANEAE: DESIDAE)

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Abstract

Observations of the biology of the spider genus *Corasoides* Butler, 1929 from Australia and New Guinea are presented from a study of both captive and field individuals. Details are provided on habitat, population density, web building, prey capture, courtship and mating, eggs, life cycle, parasites, parasitoids and predators. A new purpose (web protection from falling debris) is proposed for the overhead labyrinth of the web.

Keywords: spider captive breeding, genital plugging, ballooning, co-habitation, generational overlap, spider parasitoids, labyrinth spiders, trampoline spiders, web dashers.

Introduction

The genus *Corasoides* was revised by Humphrey (2017) and now includes 10 species: *C. australis* Butler, 1929 (type species of the genus), *C. angusi*, Humphrey 2017, *C. cowanae* Humphrey, 2017, *C. motumae* Humphrey, 2017, *C. mouldsi* Humphrey, 2017, *C. nebulae* Humphrey, 2017, *C. occidentalis,* Humphrey, 2017, *C. stellaris* Humphrey, 2017 and *C. terania* Humphrey, 2017. *Corasoides* species are commonly called platform-weaving spiders, labyrinth spiders, trampoline spiders or web dashers and they run on the upper surface of a more or less horizontal platform web. They are small to large spiders and have large chelicerae and a distinctive abdominal pattern (Figs 1, 2).They are found in most habitats through much of eastern, southern and western Australia and in the mist forests of Papua New Guinea (Humphrey 2017) (Fig. 3).

Brief accounts of the biology of these spiders can be found in Anonymous (1981) (where the plates of the spider and web are printed upside down), Clyne (1969), Main (1964, 1976, 1982), Nichols (1976), Mascord (1977), Hunt (1982), Simon-Brunet (1994) (where the plate is upside down), Lindsey (1998), Preston-Mafham (1996, 1998), Archer (2010), Framenau *et al.* (2014) and Whyte and Anderson (2017). Most of these accounts refer to *C. australis* or provide insufficient information to identify the species involved. Main (1964, 1976) refers to *C. australis* and also what could later be prescribed as *C. occidentalis* and Main (1982) as *C. angusi* and similarly Nichols (1976) to *C. occidentalis.*

Materials and methods

Spiders were observed both in captivity and in the field over an eight year period. In captivity, burrowing spiders were housed separately either in a glass aquarium or in a six litre, transparent, plastic container. These plastic containers were preferable to aquaria as they had small, flip-top openings that caused minimal disturbance to the spider when prey was added. Containers were supplied with

Figs 1, 2. *Corasoides* spp. (1) female *C. angusi* on web, Kuper Range, PNG. (2) male *C. occidentalis,* Perth, WA. (photo D. Knowles).

approximately two centimetres deep of soil (of a type the same or similar to that of the original habitat), a container of water, and twigs and dead foliage as support for webs. Non-burrowing species were also kept in such containers, but were also observed in semi-captivity indoors where they made their retreats in the corners of windows and similar sites. Hundreds of spiders were kept during this study and many were reared through two generations. Spiders were fed on flies of suitable size, juveniles beginning on drosophilids, thereafter progressing with development to house flies (Muscidae) and finally blow flies (Calliphoridae). Moths of suitable size were also occasionally offered.

To observe courtship and mating of the non-burrowing species, containers housing a separate male and a female were connected by a tunnel of plastic shade cloth. This tunnel was approximately 50 cm long by 15 cm diameter. This arrangement enabled the male to approach the female at will and also allowed him safe retreat. Such courtships were usually successful. When a male was introduced by hand into a female's container, mating was often not successful, and the male was usually killed by the female. Some courtships and matings of *C. australis* and *C. occidentalis* were observed with females housed in purpose-built clear, acrylic containers where their burrows were restricted to a 2 cm wide panel and males were introduced onto the soil surrounding the web. This permitted observation of the inside of the burrow and also allowed the males to approach the female's web cautiously and at will. Both males and females were well fed before being given the opportunity to mate. Species were deemed to cohabit if at least one cohabiting pair was observed. Species were deemed to plug the female epigyne if at least one female was found plugged. Species were deemed not to plug the female epigyne if none of at least five adult females were unplugged in the vicinity of an adult male.

Habitat, population density and siting of webs

Australian species

Corasoides australis inhabits sclerophyll forest, heathland, scrub thicket, semi-arid spinifex and saltbush country. Populations are locally clumped and some sites may have densities of up to five adults per square metre, especially on vertical or

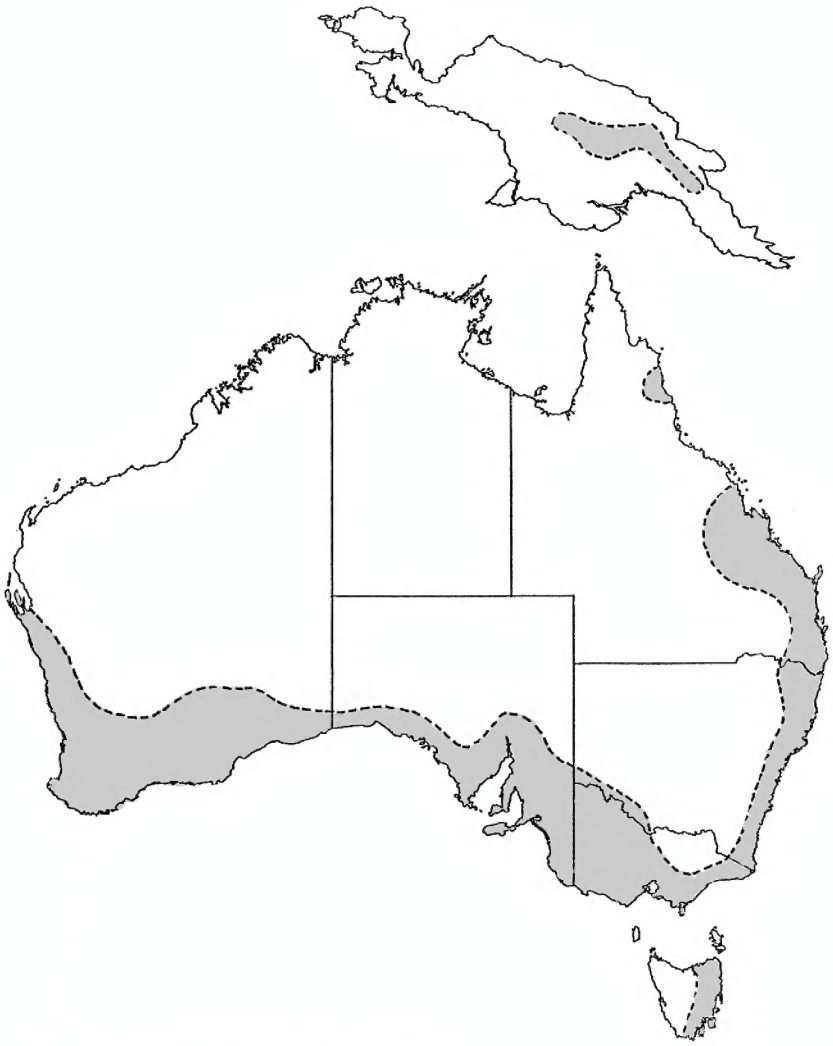


Fig. 3. Distribution map for genus *Corasoides*.

steeply inclined slopes, where webs are often tiered, one on top of the other (Fig. 4). The spiders seem to favour undisturbed areas, although they sometimes inhabit old ditches and embankments, and quiet, unused roadside verges and stock routes. Juveniles can be found in large numbers at such sites and also in grassy areas, the latter rarely used by adults (Fig. 5). Most burrows receive sun at their entrance for at least part of the day, although no pattern was found as to compass orientation of their burrows or platforms.

Figs 4, 5. *Corasoides australis*: (4) tiered webs at Eucla, WA; (5) webs of juveniles, Dubbo, NSW.

Corasoides occidentalis inhabits dry sclerophyll, woodland and heath. In a few areas west and southwest of Perth (Toodyay, Collie) this species is sympatric with *C. australis* (Humphrey 2017). Densities of one adult per square metre were found in unburnt areas of heathland in Kalbarri National Park, Western Australia. *Corasoides occidentalis*, despite being a burrowing species, appears to be poorly adapted to bushfires as adjacent areas of heathland in Kalbarri National Park, that had been burnt at least three years previously, contained no *C. occidentalis.*

Corasoides mouldsi and *C. terania* inhabit only rainforest. They prefer sites where there are breaks in the canopy that allow sunlight to their webs. *Corasoides motumae* inhabits both cool temperate rainforest and moist sclerophyll forest.

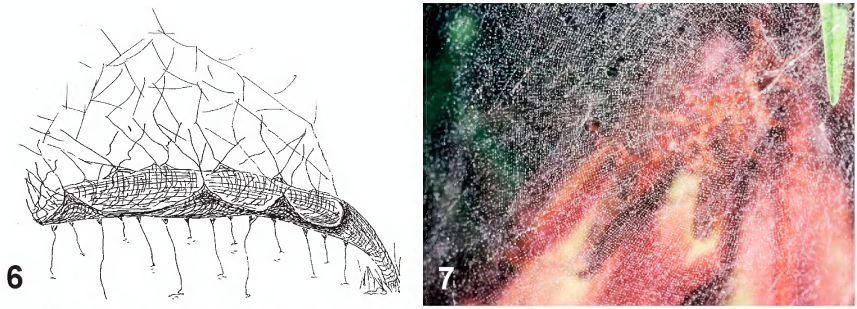
Papua New Guinean species

All the Papua New Guinean species studied inhabit high altitude rainforest. Altitudes for collection sites are *C. angusi* 1,800 m (Kuper Range), *C. nimbus* 2,500 m and 3,000m (Mt Giluwe), *C. nebula* 2,100m (near Tari), *C. stellaris* 1,600m (Mt Akrik) and *C. cowanae* 1,625m (Mt Akrik).

Large webs of what are strongly presumed to be of another Papua New Guinea *Corasoides* species were found in rainforest patches interspersed between alpine tundra/meadow at 2,100 m (near Tari). This site was only a few kilometres from where *C. nebula* was collected but the large size of the webs excluded the possibility of their belonging to *C. nebula.* The only two webs found of *C. stellaris* were in an earthen embankment in a semi cleared area adjacent to a creek.

Web structure

Corasoides builds a characteristic platform web first described by Rainbow (1897) and later by Butler (1929, 1939) and by Main (1964). The web consists of a tangled labyrinth above a largely horizontal platform with a funnel to one side, leading to a burrow or retreat (Fig. 6). The platform is held by silk lines below and at the side. Supporting lines from above are attached to the edges of the platform, leaving the upper surface of the platform free.



Figs 6, 7. (6) Typical web of *Corasoides*. (7) Close up of web weave of *C. angusi*, Kuper Range, PNG.

Above the platform there is usually a tangled labyrinth. All of the web is constructed from a non-sticky, non-cribellate silk which makes it difficult to see webs in the field unless they are covered in dew. Gregg (1961) describes the web in its dry state as glistening.

In contrast to many sheet builders, *Corasoides* moves on the upper surface of the web platform. The platform of *Corasoides* is easily recognised by the regular pattern of weaving (Fig. 7) that is unlike the seemingly random weave of other platform builders. Butler (1939) likened it to the appearance of muslin, an open mesh of regularly spaced parallel lines in a square pattern (sides approximately 0.8 mm in adult). Multiple layering of this meshwork increases as it forms the funnel leading to the burrow or retreat.

The webs of *C. australis* and *C. occidentalis* are both found among low growing bushes and grasses, usually protected by the branches or stems of supporting bushes (Figs 8, 9). Platforms built by adult *C. australis* are made 6–70 cm above the ground and can be up to 1 m in length. Measurements of around 50 cm are more usual. The shape of platforms can differ widely and may be circular, triangular, rectangular, flat, arched or bowl-shaped, even within the same area. Sometimes there is a horizontal 90° bend in the platform shortly before the burrow entrance. Main (1976) reported that *Corasoides* in a Western Australian woodland built differently shaped webs from those inhabiting forests, indicating two different species. The webs she observed probably involved the two species found in Western Australia, *C. australis* and *C. occidentalis*, but my own observations are that web shape differs as much between individuals as between species. Web size and shape seems to vary according to the availability and type of supporting material and the maturity of the spider. One platform of *C. australis*, for instance, was found to ascend vertically up a tree trunk (M. Gray, pers. com.). This web was built following a bushfire when there was no other supporting material available. Juvenile spiders of *C. australis, C. occidentalis* and *C. motumae* usually build a compact, bowl-shaped web, or a flat platform mostly parallel to the ground (Figs 10, 11). Mature spiders of *C. australis* and *C. occidentalis* often build a long, rectangular web up to 1 m long, with a U-shaped cross section, that may also arch

throughout its length (Fig. 12). The appearance of the web of *C. australis* has even been the topic of a published poem (Hall 2012).

The webs of *C. mouldsi* and *C. terania* may be bowl-shaped or long troughs up to 2 m long including the above ground funnel (Fig. 13). The platform itself can measure over a metre in length and the funnel can sometimes be equally long. However, webs half this size are more usual. *Corasoides angusi* from Papua New Guinea builds either a large, bowl-shaped web (Fig. 14) or a funnel-shaped web as wide as it is long at its extreme end.

Retreat or burrow

Species which inhabit dry regions (*C. australis* and *C. occidentalis*) actively dig a burrow. Burrows are lined only minimally with silk except near the entrance where a strong funnel may be produced, especially in reused burrows. Sand or debris are often found adhering to the outer surface of the funnel.

The burrow is usually just a simple tube with a slightly extended chamber at the end. There are usually no other entrances or chambers other than the enlargement for housing egg sacs. I have, however, kept in captivity a single female (*C.australis*) which excavated a second chamber where egg sacs were constructed and hung from the ceiling. This chamber was dug directly above the main pre-existing chamber.

The width of the burrow increases with the size of the spider, reaching up to a diameter of 2 cm. Burrows can be as shallow as 4 cm in depth in sclerophyll forest, but can reach a depth of 30 cm or more in arid areas. There was no evidence of burrowing in *C. motumae*, although some juveniles had retreats in ground litter. Most adults had retreats in tree trunks or fallen logs.

All other known species of *Corasoides* do not dig burrows. The webs of *C. terania, C. mouldsi, C. angusi* and *C. stellaris* are found between the buttress roots of trees or projecting from their retreat in rubble, fallen logs, epiphytes or mossy embankments. *Corasoides nebula* and *C. cowana*e often have poorly protected retreats in moist leaf litter or in crevices in earthen embankments. The nature of the web of *C. nimbus* is unknown.

The purpose of the labyrinth

The purpose of the labyrinth above the platform has generally been regarded as a "knock-down" structure for prey (Butler 1929, 1939; Main 1964,1976; Mascord 1970; Forster and Wilton 1973). However, the only successful prey captures I have observed in the field were of insects (Lepidoptera and Homoptera) that had fallen or blown onto the platform without touching the labyrinth. Nichols (1976) recorded catches of Orthoptera and Homoptera in webs of *C. occidentalis* in the same manner and reported that Diptera and Lepidoptera which collided with the labyrinth all escaped through it. Both in captivity and in the field, the platform is often repaired but the labyrinth is rarely replaced or repaired following natural damage. Spiders without a labyrinth to their webs continue to catch sufficient prey. The labyrinth is not essential therefore for prey capture or platform support.

Figs 8, 9. Webs of *Corasoides* spp.: (8) *C. occidentalis*, Yallingup, WA. (9) *C. australis*, Mount Colah, NSW.

In the case of *Corasoides* (and no doubt other horizontal web builders) falling debris is often a problem. Debris can both clutter and damage a web, either requiring energy to remove and to repair the damage to the web or, alternatively, reducing the prey catching surface and acting as an obstacle to rapid prey capture. In both abandoned and occupied webs of *Corasoides* in forested areas, the labyrinth is often found littered with fallen leaves and twigs while the platform below remains free of debris (Figs 13, 15, 16). Unlike vertical snares, horizontal snares are particularly prone to falling debris and subsequent damage and clutter. The importance of this is also apparent by the seemingly low incidence of *Corasoides* webs in high litter fall areas, e.g. beneath *Casuarina* trees. It is proposed, therefore, that the purpose of the labyrinth above the web is not to 'knock-down' prey, but to shield against falling debris.

Web construction

The construction of the webs of captive *C. australis* and *C. occidentalis* takes several nights. The order of the process is as follows: spinning a rough silken retreat, placing of long lines of silk from retreat site, digging a shallow burrow; spinning a funnel; construction of the platform and labyrinth, and extension of the burrow. This agrees with Rainbow's (1897) description, except that his specimen failed to build the labyrinth section. Spiders I have kept in captivity have usually built the labyrinth, but once damaged or destroyed, have failed to repair or replace it.

Old webs and burrows in good condition are undoubtedly reused (Archer 2009). Spiders taken from the field will readily occupy webs in captivity of former captive specimens and released spiders have readily taken over empty webs in the field. In spring there is a surplus of empty webs on the departure of the adult males. These webs are often occupied by young juveniles in summer and autumn. One very large web and burrow of a juvenile *C. occidentalis* excavated at Glen Forrest, east of Perth, contained a group of three, recent, unhatched egg sacs as well as three other groups of 2–4 hatched egg sacs of different ages, one group quite old and one group in an advanced state of deterioration, each older group buried beneath the other. This suggests an occupation by females for at least four

years. The funnel and burrow of this web also had been reinforced many times, thus attaining a consistency of strong, fine linen.

As a juvenile grows the spider needs a bigger web and burrow. If it does not take over another web, or extend its existing web, a new web leading from a nearby new burrow is usually built over the old web, leaving the original web intact. Nichols (1976), reported very low dispersal rates for juveniles of *C. occidentalis*. Although adults of these species always had burrows, not all young juveniles dug burrows. The webs of these juveniles ended in a funnel at ground level. Nichols (1976) reported a high mortality rate for juveniles that did not burrow. *Corasoides occidentalis* is a larger spider than *C. australis,* and its web is usually correspondingly larger.

Prey capture

Corasoides are active both day and night. Adults are often found on their platform at night repairing or extending the web. During the day, small juveniles are sometimes found on their platform apparently awaiting prey, but adult spiders are usually at the entrance to their funnels. They stand with their abdomens towards their platforms and a hind leg extended back and touching the beginning of the platform. This is in contrast to most other burrowing spiders which await prey in a head first position. When prey lands on the platform, the spider turns in the funnel and runs extremely rapidly (Archer 2009) along the upper surface of the platform to the prey. If prey is not caught and subdued quickly, it escapes through the labyrinth or over the edge of the platform. The spider will sometimes chase prey over the edge and rarely even into the labyrinth but does not leave the vicinity of the web. When caught, the prey is generally not wrapped in silk and is usually carried into the funnel or burrow. Sometimes it is consumed on the platform. Only one captive specimen of *Corasoides* (*C. motumae*) was observed wrapping prey and this was achieved by moving the whole body around the prey rather than rolling the prey with the rear legs as is common in orb weavers. Prey that fall near the funnel area usually bounce down into the burrow. The remains of meals are dumped over the edge of the platform.

Courtship and mating

Corasoides australis

In *C. australis*, courtship and mating can be of extended duration. My observations of specimens from eastern Australia show that a male in captivity may spend several days on the edge of the female's platform. I do not regard this positioning at the edge of the web as cohabitation (Jackson 1986), because the female is adult and the male makes occasional advances to the female only to be aggressively driven back. Courtship on the platform usually took place all night (approximately 12 hours in duration) and often involved several hours of the male standing motionless on the platform after retreating from the female. This was interspersed with advances and periods of palp grooming, that is, passing the palps and fore tarsi through his mouth. This was interspersed with a rapid, horizontal flicking movement of his palps. When the male had advanced to within

Figs 10, 11. Juvenile webs of *Corasoides australis*, Hornsby, NSW.

touching distance of the female, he stood high on his legs and jerked first his palps and mouth area and then his abdomen in a side to side manner. The female replied with side to side twitches of her palps. After contact, jerking and palp grooming continued but the male also frequently twitched his body – a single, slight vertical movement more obvious in the abdomen. Mating took place inside the burrow with the female either facing towards the platform or in the funnel section of the web facing downwards into the burrow, but with the entrance blocked by the body of the male. The male was positioned beneath the female, facing in the opposite direction (Fig. 17a). This is mating position 1 described by Gerhardt and Kaestner (1937–8). Each palp was applied separately to the nearest epigynal opening. Coupling was repeated many times over several hours.

Gregg (1961) describes the mating in captivity of *C. australis* (wrongly identified as *Ixeuticus longinuus*, sic) from the Sydney region. Unfortunately his observations followed the introduction of a female onto a male's web, a particularly unnatural occurrence. Gregg, however, reported that the male's courtship involved tapping of the web with the palps, stroking of the female with his fore legs, body twitching, a head-to-head mating position, repeated matings, the use of palps alternately and the cleaning of the palps after each mating. His paper also implied that mating occurred with uncharged palps before weaving a sperm web, sperm induction and subsequent re-mating (sperm webs are built by males for depositing sperm).

Courtships and matings from specimens of *C. australis* from Western Australia and South Australia are essentially the same, although some slight differences were noted. In Coolgardie specimens, the males displayed much rubbing of their forelegs upon their palps and grooming of their fore claws while waiting on the platform. They also exhibited rubbing of their palps against the female's palps and vibrating of their palps against the epigyne just prior to insertion. One male

was observed to interrupt courtship to capture a large mosquito on the platform, partially consume it and then resume courtship while still holding the prey.

The mating position of these Western Australian and South Australian specimens was similar to Gerhardt's position 1, except that the male was at an angle of approximately 45° under the female and turned slightly to one side (Fig. 17b). His first pair of legs was raised and holding back the forelegs of the female. One male was beneath the female but well off to her side. The first and second legs on the near side of this male passed over the female's cephalothorax and the palps were passed sideways to her epigyne. This is similar to Gerhardt's position 5 except that the spiders faced in opposite directions and the male's fore legs held back the female's forelegs (Fig.17c). It can therefore be seen that the copulation position is not constant within this species.

The longest copulation observed was nine minutes but repeated copulations over several hours totalled at least 50 minutes. Although impregnation of the female was achieved each time, male *C. australis* were sometimes killed and consumed by the female while still in the burrow.

The epigyne of the female is not plugged during mating and females may mate with more than one male.

Other species

Unlike *C. australis*, mature males of *C. occidentalis, C. terania, C. mouldsi, C. motumae* and *C. angusi* can be found cohabiting with penultimate, or occasionally mature, females. Cohabitation in spiders is a common phenomenon that Jackson (1986) regards as primitive (plesiomorphic) and which he concluded tended to occur in those spiders in which the female mated only once. Disturbance of webs of these *Corasoides* species was often met during the mating season by the advance of an aggressive male, running from the retreat or burrow which he shared with an immature female, his chelicerae spread wide, while the female remained hidden. Mating is presumed to occur only once for each female of *C. occidentalis, C. terania, C. motumae* and *C. mouldsi* as it results in the plugging of the female epigyne. However, plugging of the epigyne may not necessarily prevent further mating by the female. Jackson (1980) reported the displacement of spider plugs in Salticidae as a result of a second copulation and Eberhard (1985) discussed by-passing of female plugs in many invertebrate species.

Courtships of *C. occidentalis* (Stirling Ranges specimens) was characterised by web tapping with both palps simultaneously, head to head butting, jerky, jiggling movements of the male on the platform, vibrating of palps under the female's abdomen with both palps at once, insertion of palps, one at a time and sometimes crossing the palp across the epigyne to insert it in the genital opening furthest away. The male's mating position was like that of *C. australis*, ranging from the almost parallel position of eastern *C. australis* to about 45° (Figs 17a, b), this more upright position appearing the most common. The side-by-side variation (Fig. 17c) was also observed in a pair from the Stirling Ranges. Courtship times

Fig. 12. Adult web of *Corasoides occidentalis*, Nannup, WA.

(before copulation) of *C. occidentalis* were about half the courtship times of *C. australis*.

Corasoides terania and *C. mouldsi* also do not have the extended precourtship of *C. australis*, whereby the male spends hours if not days motionless on the edge of the platform. This is no doubt unnecessary since the male would normally have been cohabiting with the female for some time. One successful courtship of *C. terania* took less than three minutes. Courtship observed in captivity of a male coming upon an unmated, adult female was characterised by initial web tapping by the male's palps and then steady, left, right, left, right drumming of his palps on the web when facing the female. The male's chelicerae and often fangs, are held open while he is advancing towards the female and even during copulation. The male's mating position is even more upright than that of *C. occidentalis*. He pushes upward hard against the female so that his body is almost at 90° to the female, with her palps touching his carapace. She is held back by the male applying his first legs over her first legs and his second legs over her second legs. This is similar to Gerhardt's position 1 except for the placement of the male's fore legs (Fig. 17d) and is regarded as primitive, being common in mygalomorphs. Any forward advance by the female was resisted in this way. The male palps were observed being inserted, first, both together and then half an hour later, at a second mating by the same male to the same female, one at a time, (right palp to left side of female and vice versa). One mating of *C. terania* continued on the underside of the platform after the female had retreated there.

I have observed males of *C. terania* and *C. mouldsi* in the field resident with plugged and obviously gravid females. One male *C. terania* was resident with a female who had a recently constructed egg sac in her retreat. If these males are not fathers in residence then it would appear that they are potential new mates despite the epigynal plugging of the females.

Only one *C. terania* male and one *C. occidentalis* (from Stirling Ranges) were observed building sperm webs, in both cases after a night of mating. This building of the sperm web occurred directly after an apparently successful mating but I could find no evidence of a sperm web before the male entered the female's web. It is possible that this is a case of preliminary copulation before the priming of the palps as discussed by Eberhard (1985), van Helsdingen (1965) and Kullmann (1964), and is also implied by Gregg's (1961) observations.

The sperm web of *C. occidentalis* was constructed just above the ground but the construction of the sperm web of *C. terania* was carried out from the female's web. The male bit a hole in the platform of the female's web and lowered his cephalothorax and abdomen through the hole. While remaining upright and with his legs still above on the female's platform, he spun a small, white, triangular platform parallel to the female's web. This construction took about 15 minutes. Silk was laid down on both the upper and lower surfaces of the sperm web. The sperm web was approximately the size of the male's cephalothorax. The male then raised his cephalothorax onto the female's platform but bent his abdomen down through the hole to deposit sperm in a droplet on the edge of the sperm web (Fig. 18). Raising his body again onto the female's platform, he passed his palps through the hole, alternately, one at a time, several times and applied each palp to the sperm droplet for about 45 seconds each time. Complete recharging of the palps took five minutes and the spider then attempted unsuccessfully to mate again with the same female.

Little is known of the mating behaviour of any of the Papua New Guinea species. Both adults and juveniles were available during the dry season. A male *C. angusi* was found in the web of a female but males of other Papua New Guinea species were not found in the webs of females. Despite the presence of adult males in the immediate area, all females collected of Papua New Guinea species were unplugged.

Life cycle

Australian species

Egg sacs of *C. australis* are usually laid in late summer but were recorded from October to February. Incubation usually took around 47 days, but in some cases, particularly for spiders' first egg sacs, it could be more than two months. Spiderlings in captivity remained around the egg sac for a few days after hatching and then gathered at the highest point of the platform web. The first moult outside the egg sac takes place 2–3weeks after hatching. No ballooning was observed even when ballooning was encouraged by allowing spiderlings their freedom and

Figs 13, 14. Webs of *Corasoides* spp.: (13). *C. terania*, Terania Creek, NSW. (14). *C. angusi*, Kuper Range, PNG.

Fig. 15. Web of *Corasoides terania* with light debris, Terania Creek, NSW.

providing them with a gentle breeze simulated by an electric fan. Savory (1977) pointed out that ballooning is known only in a small proportion of spiders and appears to be a temperate phenomenon. Bristowe (1939) noted that mass aerial dispersals are not known in tropical areas, however, Robinson (1982) suggested that ballooning may occur sporadically, not *en masse*, and therefore may not be conspicuous. B.Y. Main (pers. comm.) reported *Corasoides* in sites where access would appear to be possible only by ballooning, and Nichols (1976) recorded *Corasoides* spiderlings (likely *C. occidentalis*) on aerial sticky traps. Even so, these spiderlings do not appear to disperse far.

Captive observations indicate that one of the offspring remains in possession of the parental web and reaches maturity there. This also seems to be the case in the field, where a small juvenile can often be found in possession of a large web with the wide funnel and arched construction of an adult web. Spiderlings in captivity did not disperse and build individual webs until about two weeks after hatching.

Most spiders are mature by early spring, maturation occurring about nine months after hatching. The penultimate instar takes about four weeks. However, total development from hatching to adult can take 5.5–12 months. This means that adult spiders can be found at almost any time of the year, although (except for *C. motumae*) they are particularly scarce in autumn. Most adult males leave their webs in early spring to search for females and by early summer, approximately 30% of webs in the field will be unoccupied and most of those occupied contain females. All males in captivity died within 3–5 weeks of reaching sexual maturity whether or not they had successfully mated.

Mating usually takes place from late winter to early summer, depending upon when adults reach maturity. However, late summer matings are possible between older, late developing adults. This means that eggs can be laid, theoretically, from early spring (from late winter matings) to autumn (late summer matings). Depending upon the abundance of prey, maturation rate and climate, new adults from these eggs could then be in the field any time from late summer to the autumn of the next year. Such overlapping of life cycles would result in more extensive gene flow than is possible if the spiders had a well proscribed annual life cycle.

The first egg sac is produced by the female from nine days to about four weeks after mating and a single mating can produce fertile eggs up to 2.5 months later. The female may produce up to five egg sacs. Butler (1939) states that the egg sacs are guarded by the female until the spiderlings hatch. When a burrow has been disturbed, I have sometimes observed females on, and apparently guarding, a fresh, hanging egg sac, but I have not observed any apparent guarding of older egg sacs that are on the floor of the burrow. Also since Butler does not record the hatching of spiderlings and also states that it is unknown how long the young remain in the maternal home, it seems that the length of this apparent guarding by the female may be a presumption on his part. Despite having dug up hundreds of burrows in the field over ten years, I have not found a single female with hatched young or a recently hatched egg sac with her in her burrow. Similarly, in captivity, all females died in the late summer or early autumn, within a few days of producing their last (and usually smallest) egg sac and shortly before the appearance of their first spiderlings.

Nichols (1976) believed that (what were most likely) *C. occidentalis* reached sexual maturity after about 18 months. He reported that females lived for a total of two years but that males died about a month after reaching maturity. However he also documented that some males mature in as little as five months. He reported a division of adult females collected in the field into two groups (one year olds and

Fig. 16. Female *Corasoides terania* (arrowed) moving on web platform despite heavy load of debris above, Terania Creek, NSW.

two year olds) based on leg length, funnel diameter and web length. However, examination of his data showed these measurements were continuous for both leg length and web length and with only a possibility of a disjunction in funnel diameter. However funnel diameter is often not indicative of the size or age of the inhabitant as juveniles take over unoccupied webs. In addition, Nichol's work covered only a few months of one year and he did not see a complete life cycle of any specimen.

I found that both males and females of *C. occidentalis*, *C. mouldsi,* and *C. terania* (with the exception of one male) bred in captivity over several years, reached maturity within ten months. The males died shortly after reaching maturity and the females died a few months after the first egg laying. The exceptional male *C. terania*, unlike its siblings, took 16 months instead of the usual 8–11 months to reach maturity. The annual seasonal life cycle of these species closely followed that of *C. australis*.

I believe that overall there is insufficient evidence for a two-year life cycle for females and available evidence from captive specimens points more strongly to an annual life cycle with generational overlap by late maturing individuals.

Conversely, adult males and females and egg sacs of *C. motumae* were common in the field in April and May but individual life cycles were still annual. Egg sacs

were laid up until late October. Eggs hatched from July to December, taking two months to hatch, but spiderlings dispersed after a week. Females died in captivity from September to November and before their young hatched. Female spiderlings that hatched in captivity in early October were adult eight months later.

Corasoides mouldsi spiderlings appeared more aggressive than their *C. australis* counterparts and fought over prey in the web in their first month before dispersing. Up until their first visible moult at three–four weeks, the spiderlings of *C. mouldsi* moved in a characteristic jerky manner, darting quickly for a short distance, stopping suddenly and then darting quickly again.

Papua New Guinean species

Adult males and females as well as juveniles of *C. angusi*, were common in October when they were collected.

Corasoides stellaris is known from only two specimens, an adult female and a juvenile collected in November. *C. nebula* and *C. cowanae* were collected in November when adults of both males and females as well as juveniles were common. *C. nimbus* specimens were collected as adults in July.

Egg sacs

Corasoides australis

Before egg laying, female *C. australis* excavate an extension to the bottom of their burrow leaving a horizontal ceiling for egg sac attachment. Further enlargements to this chamber may be dug later for additional egg sacs or a separate chamber may be constructed. Unwanted excavated soil was carried in the chelicerae and dropped over the edge of the web platform, but some was retained and incorporated into the egg sac. The first egg sac was observed nine days after mating, but some females did not produce their first egg sac until up to four weeks after mating.

Although Butler (1939) reported only about 35 eggs, and Mascord (1970) reported 40–55, I have found the egg sac of *C. australis* to contain 62–80 cream to pale yellow eggs interspersed with fluffy pinkish silk inside a tough white inner silk bag with a diameter of 7–10 mm. This inner bag is surrounded by a layer (approximately 5–10 mm) of dry soil particles, usually sand grains, interspersed with silk threads. This, in turn, is surrounded by a tough outer bag of silk, decorated with soil particles and debris making a final egg sac of 13–20 mm diameter although, a female's last egg sac is often much smaller (Figs 19, 20). The incorporation of soil or similar debris into the outer layer has been recorded in *C. australis* (Butler, 1939), *Hypochilus pococki* (Catley 1993) and *Cambridgea* (Main 1976). The whole sac is attached to the egg chamber ceiling by a silken cord whose threads are continuous with the threads around the outside of the egg sac (Figs 19, 20).

Observations of captive females showed that they began construction at night by spinning a disc of white silk on the floor of the burrow. They laid their mass of shiny pale yellow eggs onto one side of the upper surface of this disc and then

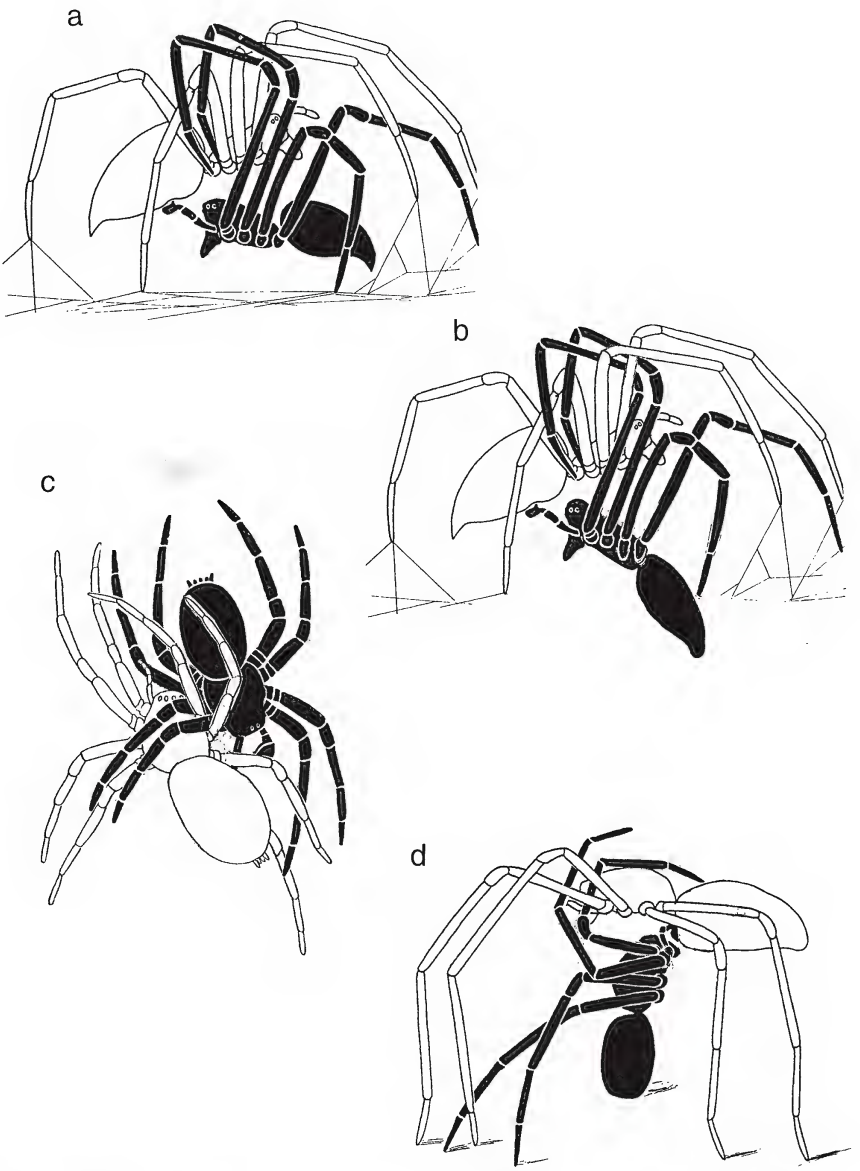


Fig. 17. Mating positions of *Corasoides* spp.: (a) Eastern and southern *C. australis* and *C. occidentalis* from Stirling Ranges, WA; (b) *C. australis* from WA and *C. occidentalis* from Stirling Ranges, WA; (c) *C. australis* from Coolgardie, WA and *C. occidentalis* from Stirling Ranges, WA; (d) *C. terania* from Terania Creek, NSW and *C. mouldsi* from Windsor Tableland, Qld.

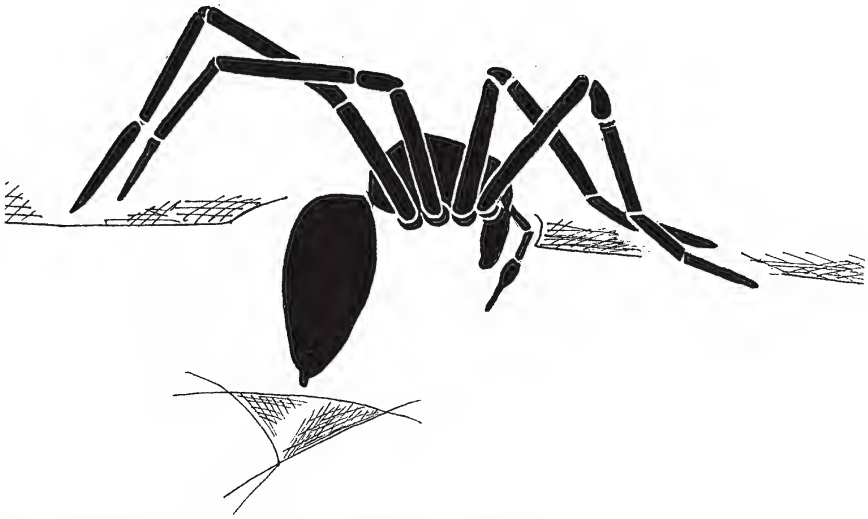
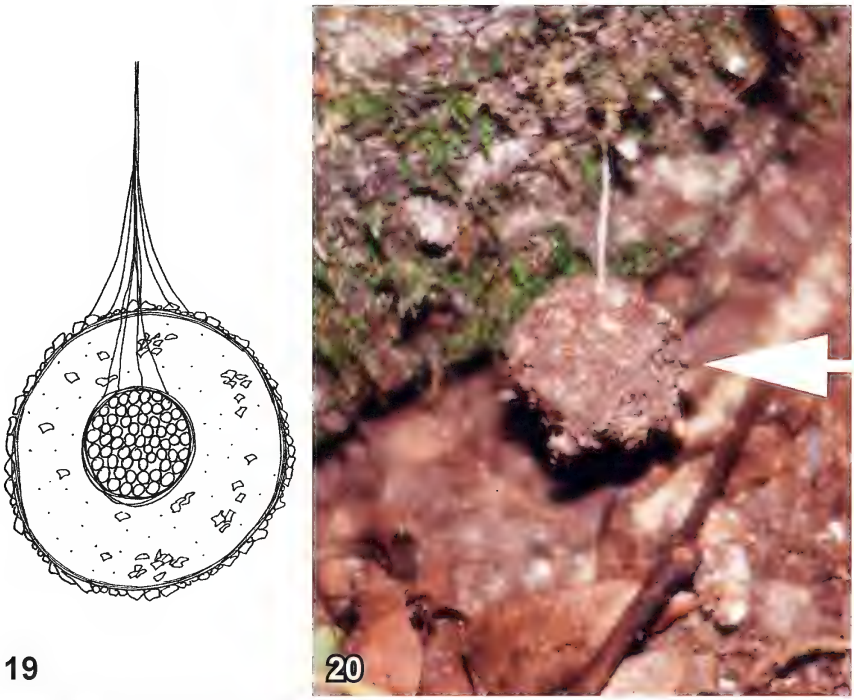


Fig. 18. Sperm web building by male *Corasoides terania*.

proceeded to deposit tufts of the pinkish silk over the top surface of the disc with jerky up and down movements of the abdomen. Formation of the inner bag from this disc and attachment to the ceiling was not observed.

Soil particles from the floor of the burrow or from excavations were carried in the chelicerae and applied to the completed and hanging inner bag with strands of silk. The spiders hung head down on the bag and applied the soil in a circular manner or up and down by rotating the bag with their legs. However, the laying down of the outer bag is by short applications of the spinnerets, the female moving around the egg sac. The time of construction from inner bag construction to final completion takes about nine hours.

The finished egg sac may hang by its cord for several weeks or even months until hatching but usually by then it is on the floor of the burrow. Despite the excavation of many burrows, I have not found more than one egg sac hanging from the ceiling at any one time. All older egg sacs, hatched or unhatched, have been on the floor of the chamber. Since I have observed egg sacs still hanging from the ceiling only 12 hours before the appearance of new egg sacs, and since any subsequent egg sac always hangs from the same site as the previous egg sac, it seems that the female is responsible for the deliberate removal of the previous egg sac from the ceiling of the burrow. Alternatively, it is possible that the female's movement in the area causes the breakage of the supporting cord. However, since no older egg sacs have been seen to remain suspended, it seems more likely that the female deliberately removes the previous sac, perhaps by biting through the supporting cord. This is contrary to Butler (1939) who stated that the egg sacs were removed from their hanging position by the female directly after completion.



Figs 19, 20. *Corasoides* spp. (19). Transverse section of egg sac. (20). Hanging egg sac of *C. australis*, Fraser Island, Qld.

Spiderlings were observed to emerge from a single pinhole in the egg sac from three weeks to three months after the eggs were laid.

Other species

The egg sacs of *C. occidentalis, C. mouldsi* and *C. terania* are similar in structure to those of *C. australis,* but larger. These egg sacs measured 21–28 mm in diameter although the last sacs before a female's death were often much smaller. The soil or debris in the intermediate layer and on the outside covering of egg sacs of rainforest species was of leaf litter and similar material rather than the sand grains available to and used by *C. australis* and *C. occidentalis.* Eggs were creamy yellow to very pale olive green. The number of eggs observed per sac was 126–134 for *C. terania* and 71–127 for *C. mouldsi.*

Egg sacs are not known for any of the species from Papua New Guinea.

Parasites, parasites and predators

The most obvious functions of the thick soil layer in the egg sacs would appear to be resistance to desiccation and/or the prevention of attack by predators or parasitoids (*sensu* Austin 1985). However, Nichols (1976) in his work on *C. occidentalis* concluded that the resistance to desiccation of eggs in *Corasoides*

egg sacs was not of significance. Since the soil/debris layer is evident in all the rainforest species of *Corasoides* in Australia, it would seem that its purpose is not prevention of desiccation. Parasitoid and predator resistance therefore appears to be a more logical explanation. As with other spiders (Austin 1985) it appears to be successful. In ten years I found only one parasitised egg sac from which several wasps emerged. Some egg sacs were, however, unproductive in that no spiderlings emerged. When investigated these showed either eggs covered with fungal growth or intact, but dead, young spiderlings.

Two adult female spiders of *C. terania* were each found parasitised by a single large nematode that filled most of the abdomen. One adult male (*C. australis*) was found with numerous orange mites attached to the abdomen and the intersegmental membranes of the legs.

The burrows of two adults (*C. australis*) were each found to be occupied by a large and well-fed wolf spider (Lycosidae). As the webs and burrows were in excellent condition, it would appear both had been recently occupied by the spider, and the only access to the burrow would have been across the platform of the web. However, it is possible the wolf spiders, rather than prey on the residents, had taken over a vacant web and burrow.

As well as a high mortality in the first four months caused by unfavourable climatic conditions, Nichols (1976) reported predation of *Corasoides* spiderlings by ants.

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A NEW CICADA SPECIES, *HAEMOPSALTA EXIMIA* (HEMIPTERA: CICADIDAE) FROM NORTH-WESTERN SYDNEY, AUSTRALIA

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Abstract

A new cicada species, *Haemopsalta eximia* **sp. n.,** is described from Australia bringing the number of species in the genus to five. The species is known from a 250 km^2 area in the Hawkesbury and Colo River regions in the north-west of Greater Sydney. Its recorded male song is illustrated and discussed.

Keywords: cicadas, New South Wales, eucalypt forests, song recording, new species

Introduction

In their revision of the cicada genera *Pauropsalta* Goding and Froggatt, 1904, *Palapsalta* Moulds, 2012, and *Uradolichos* Moulds, 2012, Owen and Moulds (2016) erected the genera *Atrapsalta*, *Falcatpsalta*, *Haemopsalta*, *Popplepsalta* and *Relictapsalta*. After clarifying historical species and describing 22 new species in these eight allied genera, the revised genera contain 24 species of *Pauropsalta*, nine species of *Atrapsalta*, four species of *Haemopsalta*, eight species of *Palapsalta*, 15 species of *Popplepsalta*, and one each of *Falcatpsalta* and *Relictapsalta* (Owen and Moulds 2016; Emery *et al*. 2018). The species in the revised *Pauropsalta* are distinctive in possessing an infuscation of vein 2A on the hind wing, abutted or fusion of forewing veins M and CuA, head as wide as or narrower than the mesonotum, exceptionally large upper pygofer lobes, and an ornamented apex of the endotheca (Moulds 2012). The 33 species in *Pauropsalta* and *Atrapsalta* each have five apical cells in the hindwing, exceptions being *P. infrasila* Moulds, 1987, *P. infuscata* (Goding and Froggatt, 1904) and *A. vinea* Owen and Moulds, 2016, which possess six cells as occurs in species of *Haemopsalta*. With additional features in the genitalia, the current species in *Haemopsalta* comprise *H. aktites* (Ewart, 1989), found along coastal sand dunes of New South Wales and southern Queensland, *H. rubea* (Goding and Froggatt, 1904), inhabiting eucalypts in sclerophyll forests along the east coast of Australia, *H. flammeata* (Owen and Moulds, 2016) and *H. georgina* (Owen and Moulds, 2016) which have distributions limited to Expedition Range in Queensland and to Tasmania, respectively.

Here we describe a new species, the morphology and song of which most closely resemble species of *Haemopsalta* (Owen and Moulds, 2016). Consequently, we erect *H. eximia* **sp. n.,** a species with its known distribution currently limited to a 250 km^2 region of dry sclerophyll forest around Dhurag, Yengo and Wollemi National Parks on the northwest outskirts of Sydney, New South Wales (NSW).

Materials and Methods

Anatomical terminology follows Moulds (2005, 2012) for body structures and wing characters, Moulds (2005) for genitalia, and Dugdale (1972) and Bennet-Clark (1997) for timbals. The long timbal ribs are referred to as long ribs 1 to 5, with long rib 1 being the most posterior (adjacent to timbal plate). The higher classification adopted in this paper for *Haemopsalta* follows Owen and Moulds (2016). Measurements (in mm) are given as ranges and means (in parentheses) and include the largest and smallest specimens. Head width is across the eyes; pronotum width is across the extremities of the lateral angles; abdomen width is measured across the outer edges of the auditory capsules. Specimens were examined and photographed with an Olympus SZ61 stereo microscope and Cell-sens ™ software.

Male genitalia were removed using surgical scissors and placed in 10% potassium hydroxide overnight at room temperature to clear the soft tissues and provide a clean dissection. Following clearing, the specimens were washed with ethanol and placed in either 70% ethanol or glycerol. The aedeagus was flexed posteriorly and examined under 10x magnification. Measurements were taken using a pair of Supatool™ digital calipers, (DE), accurate to 0.01 mm.

Calling song analysis: song terminology follows Popple (2013) and analysis follows Emery *et al.* (2019). A 'syllable' refers to the shortest duration unit of sound produced. A grouping of repeated syllables with measurable silent gaps between each syllable is referred to as a 'syllable sequence'. The coalescence of groups of syllables is referred to as an 'echeme'. When the song contains multiple echemes or combinations of echemes and syllables that form a repetitive structure, the term 'phrase' is used to describe each repeated unit. Calling song analysis used Cool Edit Pro (2.0) software. The dominant frequency of calling song was the main frequency (pitch) element examined and was measured as the highest single amplitude reading on a Fast Fourier Transform (FFT) spectrum, over a 50–100 ms clip of high quality recording (1024 FFT size, Blackman Harris representation with a linear frequency axis). Recordings were checked for potential background interference before running the analysis.

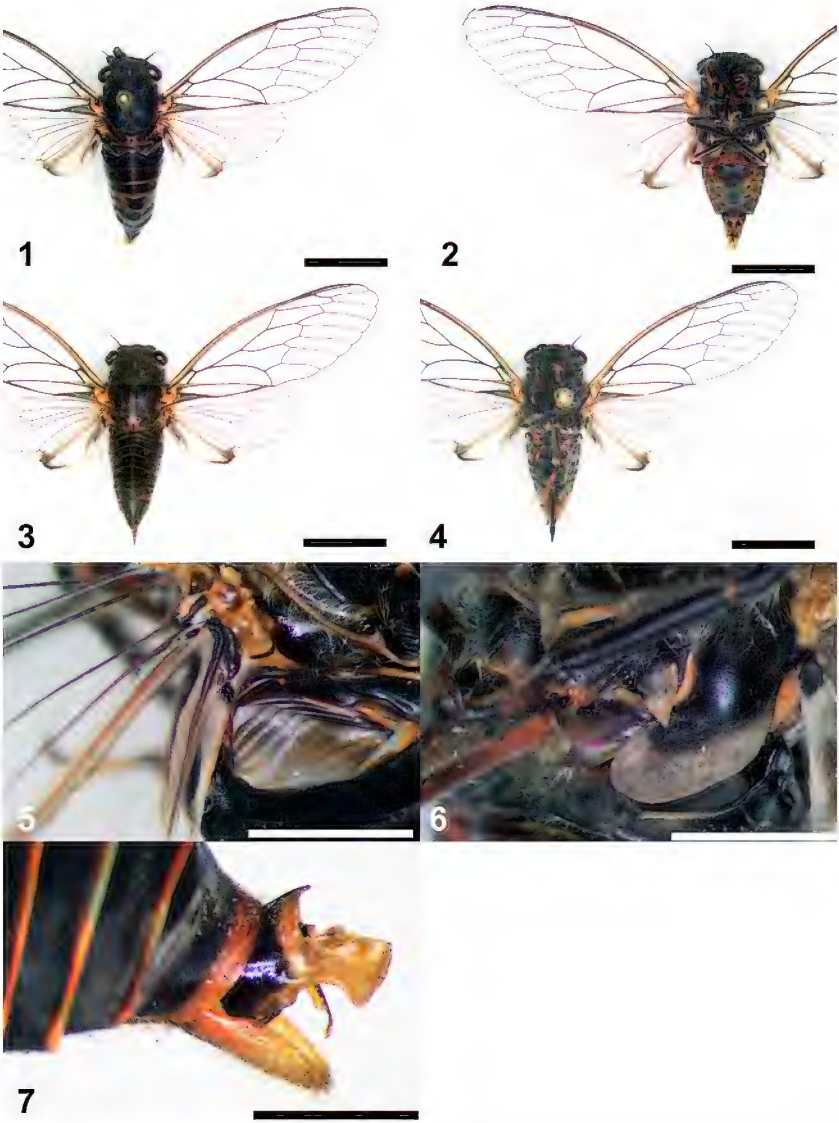
Abbreviations used in the text are as follows: AM – Australian Museum, Sydney; DE – Private collection of Prof. D. Emery, Sydney; JP – private collection of Joel Poyitt, Sydney; LWP – private collection of Dr L.W. Popple, Cairns.

Systematics

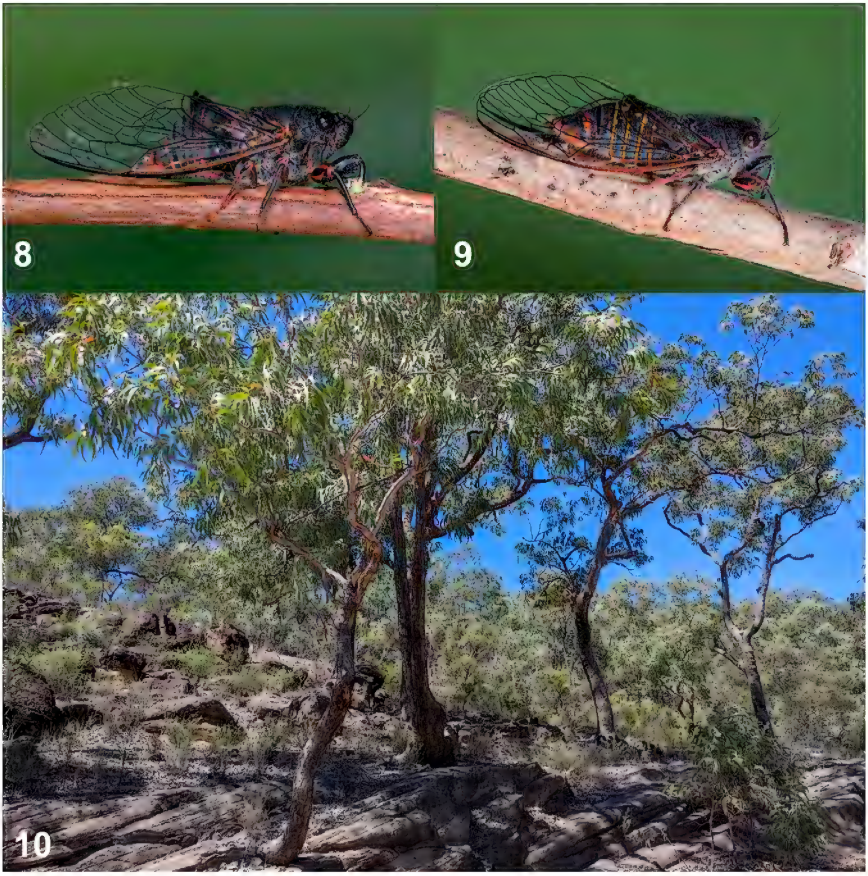
Family Cicadidae Latreille, 1802
Subfamily Cicadettinae Buckton, 1889
Tribe Cicadettini Buckton, 1889
Genus *Haemopsalta* Owen and Moulds, 2016

Haemopsalta eximia sp. n.

Type material. Holotype ♂, Comleroy Rd, Upper Colo, 33°25'49"S 150°43'19"E, 10.x.2020, N. and D. Emery (EME0650-004) (K580348, AM).



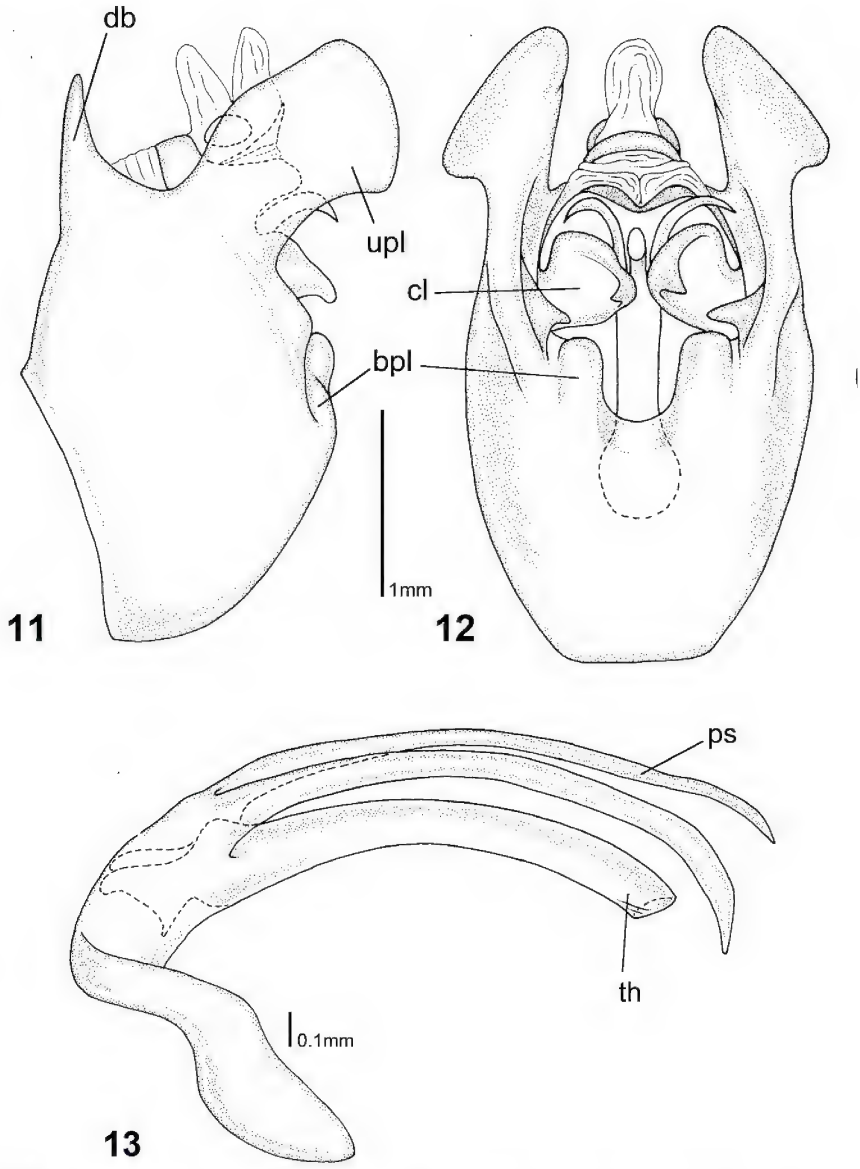
Figs 1–7. *Haemopsalta eximia* **sp. n.**: (1) Holotype male (Upper Colo, NSW, 33°25'49"S 150°43'19"E), dorsal habitus; (2) male, ventral habitus; (3) female, dorsal habitus (Upper Colo, NSW, 33°25'49"S 150°43'19"E); (4) female, ventral habitus; (5) photostack of live male left timbal, with anterior margin at top and dorsal angle at right. Specimen from Upper Colo, NSW (33°25'49"S 150°43'19"E); (6) photostack of live male left operculum, with anterior margin at top and dorsal angle at right. Specimen from Upper Colo, NSW (33°25'49"S 150°43'19"E); (7) lateral view of terminal male abdomen. Specimen from Upper Colo, NSW (33°25'49"S 150°43'19"E). (Scale bar for Figs 1–4 = 5 mm; scale bar for Figs 5–7 = 1.0 mm)



Figs 8–10. *Haemopsalta eximia* **sp. n.:** (8) live male, Upper Colo, NSW, 33°25'49"S 150°43'19"E); (9) live female, Upper Colo, NSW, 33°25'49"S 150°43'19"E); (10) typical habitat on the eastern border of Wollemi National Park, NSW, with numerous *Corymbia eximia* favoured by this species.

Paratypes. NEW SOUTH WALES: 1♂, Webbs Creek Rd, Parr State Conservation Area, 33°22'31"S 150°55'04"E, 7.x.2019, N. and D. Emery and C. Foster (EME0650-001); 1♂, 1♀, same data as holotype (EME0650-003[♂, genitalia prep], -005 [♀]); 1♂, Boree track, Yengo National Park, 33°06'0.2"S 151°2'23.4"E; 6.xi.2020, N. Emery (EME0650-008); 1♀, Comleroy Rd, Upper Colo, 33°25'32"S 150°43'31"E, 10.x.2020, N. and D. Emery (EME0650-006) (DE); 1♂, same location, 3.x.2020, J. Poyitt (JP); 1♂, Webbs Creek Rd, Parr State Conservation Area, 33°22'31"S 150°55'04"E, 7.x.2019, N. and D. Emery and C. Foster (EME0650-002); 1♀, Comleroy Rd, Upper Colo, 33°25'32"S 150°43'31"E, 10.x.2020, N. and D. Emery (EME0650-007) (LWP).

Audio recording locations: Old Northern Rd, Wiseman's Ferry, (176), 7.i.2012, B. Smith; Hawkins Lookout, Old Northern Rd, Wisemans Ferry, 33°24'14"S



Figs 11–13. *Haemopsalta eximia* **sp. n.,** male pygofer and internal genitalia of specimen from Upper Colo, NSW, 33°25'49"S 150°43'19"E: (11) pygofer, viewed laterally from the left; (12) pygofer, ventral view; (13) aedeagus. Abbreviations: as, anal styles; bp, basal plate; bpl, secondary basal lobe of pygofer; cl, clasper; db, dorsal beak; en, endotheca; ps, pseudoparameres; pyg, pygofer; unc, uncus; upl, upper lobe of pygofer; vs, ventral support.

150°59'01"E, 13.i.2015, B. Smith; Mills Creek Campground, 33°24'04"S 151°02'35"E, 14.i.2015, B. Smith; Finch's Line Track, Wiseman's Ferry, 33°24'04"S 151°02'04"E, 5.xi.2015, B. Smith; Webbs Creek Rd, Parr State Conservation Area, 33°23'20"S 151°02'03"E, 1.x.2019, N. Emery and C. Foster; 6.x.2019; Comleroy Rd, Upper Colo, 33°25'49"S 150°43'19"E, 10.x.2020, N. and D. Emery.

Description of Holotype male. (Figs 1, 2, 5–8, 11–13). Note that rather vibrant orange-red coloration of this cicada when alive (Figs 8, 9) tends to fade to orange with storage.

Head including eyes slightly wider than mesonotum but slightly narrower than lateral angles; black with ochraceous triangular stripe at posterior midline, posterior margin black, ochraceous laterally; ocelli pink; supra-antennal plate meeting or nearly meeting eye; eyes black. Postclypeus broadly rounded transversely across ventral midline, with broad black fascia on anterior and posterior midline, ventral surface black, transverse ridges black, lorum ochraceous, gena black. Anteclypeus black. Rostrum ochraceous anteriorly, black distally, extending to the centre of the mid-coxae. Antennomeres black.

Thorax. Pronotum entirely black; pronotal collar dark brown centrally and along posterior margin, black over remainder, lateral margins black with fine black pubescence. Mesonotum black, ochraceous along posterior margin, cruciform elevation ochraceous, scutal depressions black. Metanotum black, orange along posterior margins. Legs black to pale brown, basisternum 2 black, meron orange-red, fore-coxae striped orange-red and black, mid- and hind coxae black, trochanters orange-red and black. Femora striped black and burnt orange brown, femoral spines black; foreleg tibiae mainly black, mid-tibiae black with narrow ochraceous band adjacent to femoral joint, hind tibiae mainly ochraceous, spines black; foreleg pretarsal claws mainly black, mid and hind-leg tarsi with ochraceous tips, claws ringed black and dark brown, black at tips. Meracanthus black at base, ochraceous posteriorly, triangular, pointed posteriorly, marginally overlapping anterior third of opercula. Wings hyaline. Costal membranes bright orange; fore wing with stems of veins M and CuA completely fused before meeting basal cell; costal vein black, pterostigma orange-red to node, other veins black, with 8 apical cells; basal cell transparent, basal membranes stippled black. Hind wings with 6 apical cells; veins 2A, 3A and intervening wing margin orange-brown, remaining veins black, black plaga restricted to proximal half of jejum, prominent infuscation at distal end of vein 2A spread towards wing margin. Opercula black anteriorly, pale cream posteriorly, rounded apically, directed distomedially to margin of tympanal cavity, distinctly raised laterally above the tympanal cavity, clearly separated (Fig. 6). Timbals black, with four long, dark brown ribs spanning the width of timbal membrane, thinning in the central third adjacent to lighter brown intercalary ribs; long rib 5 discontinuous over the distal third of the timbal cavity, terminating at the ventral margin of the adjacent intercalary rib; basal dome large, pale brown, grooved over lateral third; timbals not reaching wing base (Fig. 5).

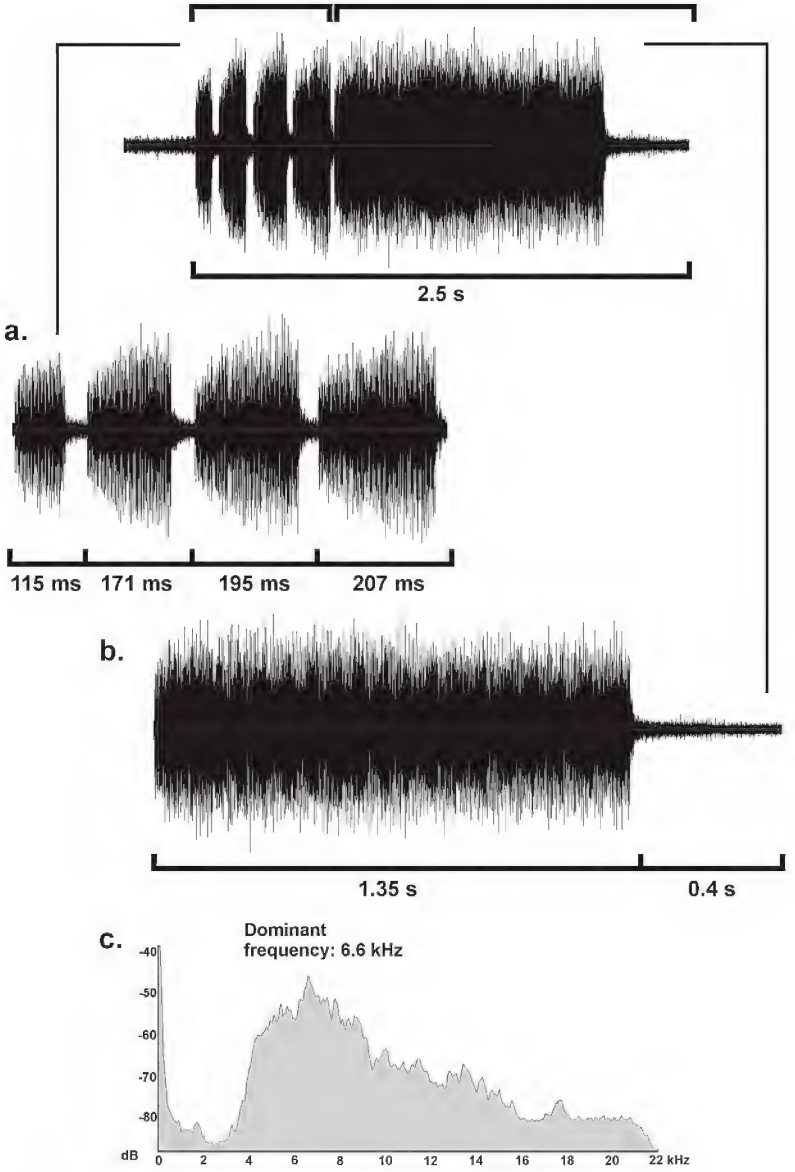


Fig. 14. Male calling song structure of *Haemopsalta eximia* **sp. n.:** (a, b) song illustrated in waveform plots. Each lower plot (a, b) is expanded from the one above, to illustrate the finer temporal structure; (c) spectrogram of song frequency. This specimen was recorded at Wollemi National Park, Upper Colo, New South Wales (33°25'34.8"S 150°43'28.3"E) by NJE.

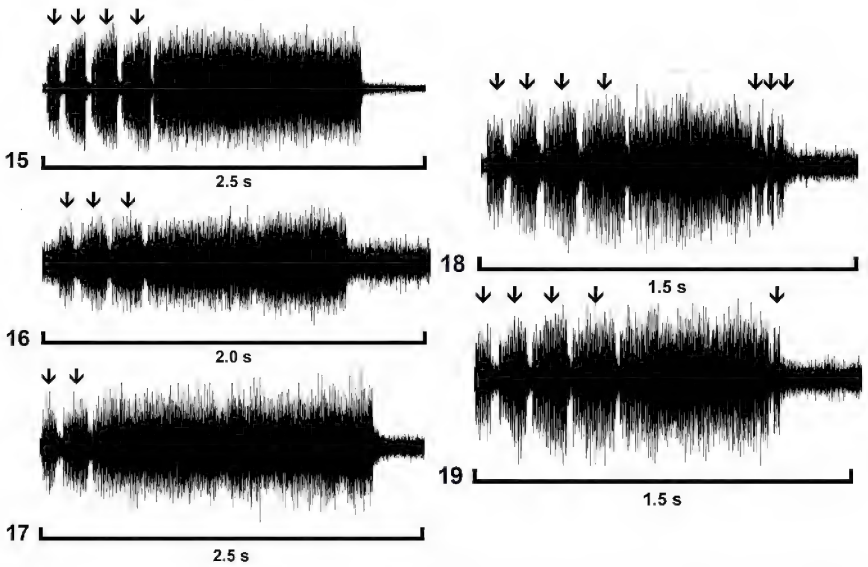
Abdomen. Tergite 1 black, narrow along dorsal midline, orange-red along timbal cavity; tergites 2–7 equivalent width longitudinally, black anteriorly, with annular red-brown to orange coloration posteriorly, becoming increasingly dominant caudally. Tergite 8 black with orange posterior margin, prominent orange coloration laterally (Fig. 2); epipleurites black anteriorly, turning red-brown to yellow posteriorly. Sternite I black, narrow, sternite II black, red over posterior lateral margins, sternites III–VI black centrally, with red-brown coloration along posterior margins, broadening laterally, sternite VII black, orange-brown posteriorly, sternite VIII red-brown anteriorly, becoming stippled black and orange posteriorly, with pale brown pubescence (Fig. 7).

Genitalia (Figs 11–13). Pygofer with basal margin of upper lobe strongly angled around 80° to the axis of pygofer, broad, pale brown; pygofer basal lobe stumpy with rounded apex, outer face ridged longitudinally in lateral view, in ventral view, mildly triangulate, angled inwards; secondary basal lobe slightly raised and broadly rounded, in ventral view parallel-sided, dome-like with rounded apex (Fig. 11). Uncus broadly rounded dorsally, slightly depressed along dorsal midline. Claspers closely applied to aedeagus, in lateral view beak-like, protruding marginally beyond margin of pygofer, claw-like with basal region projecting centrally over theca and medial margin reflected laterally to a bluntly pointed apex (Fig. 12). Aedeagus with basal plate arced in lateral view; in dorsal view Y-shaped; thecal shaft gently curved; pseudoparameres arising independently at the thecal base, rounded laterally, extending just beyond apex of theca; endothecal shaft parallel-sided, thecal apex entirely chitinized, vesical opening at thecal apex, apical margin weakly serrated (Fig. 13).

Female (Figs 3, 4, 9). Head and thorax similar to male; mesonotum with symmetrical red-brown, elongated triangular marking between inter-sigillar gap almost linking with anterior arms of cruciform elevation, remainder black except for red-brown cruciform elevation.

Abdomen. Similar to male. Tergites with annular, posterior orange-brown coloration less pronounced. Sternites black with orange-brown lateral margins, abdominal segment 9 black along dorsal midline, black lateral stripe, orange over remainder with lateral black spot, dorsal beak black. Ovipositor sheath long, black, ovipositor dark brown, black at tip, extending 0.5–0.8 mm beyond apex of abdomen.

Measurements. Range and mean (in mm) for 6♂ and 3♀; includes all available specimens. Length of body: male, 16.3–18.1 (17.1); female, 15.1–18.9 (16.9). Length of forewing: male, 18.2–20.8 (19.8); female, 18.2–23.0 (20.1). Width of forewing: male, 6.7–7.9 (7.4); female, 6.7–7.5 (7.0). Width of head (including eyes): male, 5.0–5.6 (5.4); female, 4.9–5.9 (5.4). Width of pronotum (across lateral angles): male, 4.7–5.2 (5.0); female, 4.6–5.4 (5.0). Abdominal width (across segment II): male, 4.8–5.5 (5.1); female, 4.7–5.3 (5.0). Ovipositor length: 4.1–4.8 (4.5).



Figs 15–19. Waveform plots illustrating variation in calling song phrase of *Haemopsalta eximia* **sp. n.** across three different localities: (15,18,19) Wollemi National Park, Upper Colo (33°25'34.8"S 150°43'28.3"E; (16) Parr State Conservation Area (33°23'20"S 151°02'03"E; (17)Wisemans Ferry (33°24'04"S 151°02'04"E. Durations of the phrase are provided above in each figure. The phrase typically commences with four short echemes followed by a long echeme (15). In some calling songs, number of short echemes may be reduced to either three (16) or two (17). Similarly, the phrase may be completed with a short echeme comprising between 1–4 coalesced syllables (18, 19). Recordings 15, 16, 18 and 19 were made in the field by N.J. Emery using RS1. The recording for 17 was made in the field by B. Smith using RS2 (see Methods).

Variation. Apart from size, there is very little morphological variation in the limited number of specimens of *H. eximia* **sp. n.** available.

Distinguishing features. H. eximia **sp. n.** is placed in the genus *Haemopsalta* (Owen and Moulds, 2016) due to possession of features which differentiate this genus from allied genera. It runs to couplet 79 in the dichotomous key provided in Owen and Moulds (2016) at which point it can be separated from *Atrapsalta vinea* and *Haemopsalta georgina* by the characters discussed below. With six apical cells in the hindwings, *H. eximia* **sp. n.** is readily distinguished from 30 species of *Pauropsalta* and most species of *Atrapsalta* which have five. In comparison with *P. infrasila, P. infuscata,* and *A. vinea,* with hindwing infuscations and six apical cells, the dominant black dorsal coloration of *H. eximia* **sp. n.** readily distinguishes it from the extensive orange and lighter brown dorsal coloration of *P. infrasila* and *P. infuscata*. Additionally, female *H. eximia* **sp. n.** lacks the long ovipositor of *P. infuscata*.

Atrapsalta vinea also has 6 apical cells in the hindwing and is similar in size to *H. eximia* **sp. n.** We were unable to examine a specimen of *A. vinea*, which is not illustrated in Owen and Moulds (2016). However from the description, it differs from *H. eximia* **sp. n.** by the following combination of characters: 1, the brownish coloration of the sternites and intersegmental membranes contrasts with the bright red-orange features on *H. eximia* **sp. n.**; 2, the inner spine-like projection on the basal lobe of the pygofer is absent in *H. eximia* **sp. n.,** and; 3, the pronotal collar of *H. eximia* **sp. n.** is ampliate laterally in contrast to *A. vinea*; 4, sternite VIII is red-brown in *H. eximia* **sp. n.,** but muddy yellow in *A. vinea*; and, 5, *A. vinea* which has muddy pale yellow or grey membranes at the wing bases and leg joints; those of *H. eximia* **sp. n.** are reddish orange. In addition, the species are separated geographically, as *A. vinea* occurs from the Clare district, northwards around 250 km to Wilpena Pound in South Australia. The genitalia of male *H. eximia* **sp. n.** have a reduced dome structure of the uncus, larger beak-like claspers, and a relative lack of ornamentation and widening at the thecal apex when compared to *A. vinea*.

Amongst the four *Haemopsalta* species, *H. eximia* **sp. n.** has the most prominent hindwing infuscations. Specimens are larger than *H. aktites*, which has a forewing length <17.5 mm. Males of *H. eximia* **sp. n.** also differ from those of *H. aktites* and *H. flammeata* in having a broad black fascia along the entire midline of the sternites. In addition, these 3 species are separated geographically, with *H. flammeata* restricted to Expedition Range in Qld and *H. aktites* inhabiting the coastal wattle (*Acacia longifolia* subsp. *sophorae* (Labill.) F.Muell., pers. obs.) along the eastern seaboard. *Haemopsalta eximia* **sp. n.** differs from specimens in the *H. rubea* complex in the following three features: 1, pronotal collar is largely black in *H. eximia* **sp. n.,** but ochraceous in *H. rubea*; 2, tergites of *H. eximia* **sp. n.** are black, with reddish yellow markings restricted to the posterior margins while the lateral borders of the tergites of *H. rubea* are orange-brown; 3, female *H. rubea* is predominantly brown with extensive pale orange-ochraceous coloration over the dorsal surface, whereas these areas of *H. eximia* **sp. n.** are mainly black.

Haemopsalta eximia **sp. n.** most closely resembles *H. georgina* from Tasmania but can be distinguished from it by several features: 1, *H. eximia* **sp. n.** has more prominent hindwing infuscations; and 2, it has reddish orange membranes at the wing bases and leg joints while those of *H. georgina* are much paler orange-brown; 3, sternite VIII is partly black in *H. eximia* **sp. n.** and is completely orange-yellow in *H. georgina*; and 4, both species are separated geographically.

Etymology. This species name is from the Latin '*eximia*', meaning 'unique' or 'special' and is also the name of its preferred plant species, the yellow bloodwood, *Corymbia eximia* (Schauer) K.D. Hill and L.A.S. Johnson.

Habitat and Distribution (Fig. 10). *Haemopsalta eximia* **sp. n.** is known to inhabit only a 250 km^2 area bordered by Upper Colo, Webbs Creek, Laguna and Wisemans Ferry in the north-west of Greater Sydney. Populations are usually less

than 20 individuals in small pockets on ridges or open woodland, probably related to the vicinity of females. Females are usually located within 1m of the ground on smooth barked small shrubs (*Acacia, Petrophile* or *Hakea* spp.). Males commence singing within 2 m of the ground around 0900 h, and as the day warms, they move to higher locations in yellow bloodwoods. Available specimens have all been collected in October–November but male songs have been recorded through to mid-January.

Calling song of H. eximia **sp. n.** (Figs 14–19).

The calling song of *H. eximia* **sp. n.** is described from six recordings by B. Smith and N.J. Emery from four localities (Figs 15–19), with an example from Comleroy Rd, Upper Colo, NSW, 33°25'49"S 150°43'19"E in Fig. 14. Song structure consists of a monotonously repetitive phrase comprising 2–4 short echemes followed by a much longer echeme (Figs 14a, b). Four short echemes occur most frequently, with each echeme being slightly longer than the previous (first echeme length: 0.095–0.127 sec duration; second echeme length: 0.13–0.17 sec duration; third echeme length: 0.16–0.22 sec duration; fourth echeme length: 0.18–0.23 sec duration; Fig. 14b, n = 3). The long echeme typically has a duration between 0.6–2.45 sec. Shorter phrases are typically completed with an additional short echeme comprising between 1 and 4 coalesced syllables, and each syllable is between 40–80 ms duration (Fig. 14c). A phrase typically lasts between 1.2–3.5 sec duration with a period of silence ranging from 0.33–0.53 sec duration. The spectrogram of the calling song indicates a dominant frequency of 6.6 kHz (Fig.14).

The repetitive phrase and temporal kinetics of the *H. eximia* **sp. n.** song resembles those produced by *H. flammeata, H. georgina* and *H. rubea* (especially the recording of the last from Wollombi in Ewart, [1989]). In each of the species, repeated phrases mostly range from 1–3 sec and consist of a short click followed by a longer echeme (Ewart, 1989; Owen and Moulds, 2016). The song pattern of *H. aktites* varies between locations, but differs with repeated phrases of 1–2 sec, each generally consisting of a single short and long echeme (Ewart, 1989). While *H. eximia* **sp. n.** does not include a definitive "click" start to each phrase before the echeme as occurs in *H. flammeata, H. georgina* and *H. rubea*, the length of each phrase (1.2–3.5 sec) has a similar periodicity to other *Haemopsalta* species. The dominant frequency of the *H. eximia* **sp. n.** song (6.6 kHz) is also within the range of *H. flammeata* (4–8 kHz), the species which it most closely resembles morphologically.

Acknowledgements
The authors are most grateful to Bryce Smith for generous access to his range of recordings made during numerous excursions over several years before specimens of this cicada had been sighted and collected. We thank Dr Christie Foster for field assistance and recordings, Joel Poyitt for specimen data and Ms Hannah Mathews for drawing the genitalia. We appreciate constructive comments from reviewers that added clarity and quality to the manuscript.

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FIRST AUSTRALIAN RECORD OF *JAMIDES CYTA AMPHISSINA* (GROSE-SMITH, 1894) (LEPIDOPTERA: LYCAENIDAE) FROM DAUAN ISLAND, TORRES STRAIT, QUEENSLAND WITH A BRIEF DISCUSSION ON EFFECTIVENESS OF BUTTERFLY SAMPLING ON THE ISLAND

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Abstract

Jamides cyta amphissina (Grose-Smith, 1894) is newly recorded for Australia from Dauan Island, Torres Strait, Queensland. Despite it being a bright and showy species and considering the amount of robust butterfly collecting that has been undertaken on the island, it is surprising that this species, which is likely resident, has just been collected. This may suggest that current butterfly sampling on the island is perhaps underestimating butterfly species diversity, especially those species that are less vagile or have more secretive habits, such as the lycaenids. This underestimation may be an artefact of the rugged terrain of the island making accessibility difficult.

Keywords: butterfly 'hotspot', granite boulder fields, *Jamides celeno* group, monsoonal, underestimating butterfly species diversity

Introduction

Jamides Hübner, 1819 butterflies are commonly known as Ceruleans (Braby 2016) and belong to the subfamily Polyommatinae (Lycaenidae). The genus comprises about 60 species (Müller 2016) and is predominantly tropical, occurring throughout much of the Oriental, Australian and Pacific regions (Müller 2016). Braby (2000) noted two species groups within the genus, with two and three Australian species in each group respectively, *viz*. the *bochus* group containing *J. phaseli* (Mathew, 1889) and *J. amarauge* H.H. Druce, 1891, and the *celeno* group containing *J. cyta* Boisduval, 1832, *J. aleuas* C. and R. Felder, 1865 and *J. nemophila* (Butler, 1876). These five species are tropical, with only *J. phaseli* extending into the subtropics (Braby 2000).

Jamides cyta is a widespread species occurring east from Malaya, through Indonesia, Aru, New Guinea, the Solomons, and in northern Queensland at Iron Range (Parsons 1998; Braby 2016) as *J. c. claudia* (Waterhouse and Lyell, 1914). In New Guinea, *J. c. amphissina* (Grose-Smith, 1894) occurs irregularly across the island (Parsons 1998).

In this paper, I report on the first collection of *J. cyta amphissina* in Australian territory on Dauan Island. Additionally, I hypothesise why less vagile taxa such as *J. c. amphissina* and some other lycaenids, which are likely resident on the island, are observed so intermittently despite robust and consistent butterfly collecting efforts on the island over the last three decades, and particularly since 2000.

Abbreviations of collectors' names appearing on specimen labels and depository of specimens are: AAD—A.A. Davies; AIK—A.I. Knight; GW—G. Wood; GBM—G.B. Monteith; MDB—M. De Baar; TAL—T.A. Lambkin; TLIKC—Joint collection of T.A. Lambkin and A.I. Knight, Brisbane.

Specimens examined

Jamides cyta amphissina (Grose-Smith, 1894) (Figs 1, 2)

QUEENSLAND: 1♂, Dauan Island, Torres Strait, -9.414ºS 142.539ºE, 18.i.2021, TAL and AAD; 1♀, same data except, 13.i.2021 (both TLIKC).

Jamides cyta claudia (Waterhouse and Lyell, 1914) (Figs 3, 4)

QUEENSLAND: 3♂, 2nd crossing of Gordon Ck, Iron Range, Cape York Peninsula, 10.viii.2001, 11.viii.2001, 13.viii.2001, AIK; 2♂, Iron Range, Cape York Peninsula, 9.viii.2001, AIK; 2♂, Iron Range, Cape York Peninsula, 24.vi.–8.vii.1978, MDB; 1♂, W Claudie R., em. 19.xii.1985, GBM; 5♂, 1♀, 3rd crossing of Gordon Ck, Iron Range, Cape York Peninsula, 1.viii.2000, TAL; 2♀, Claudie R., Iron Range, Cape York, .xi.1986, .xii.1986, GW; 1♀, Iron Range, Cape York Peninsula, 24.vi.–8.vii.1978, MDB; 1♀, W Claudie R., em. 17.xii.1985, GBM (all TLIKC).

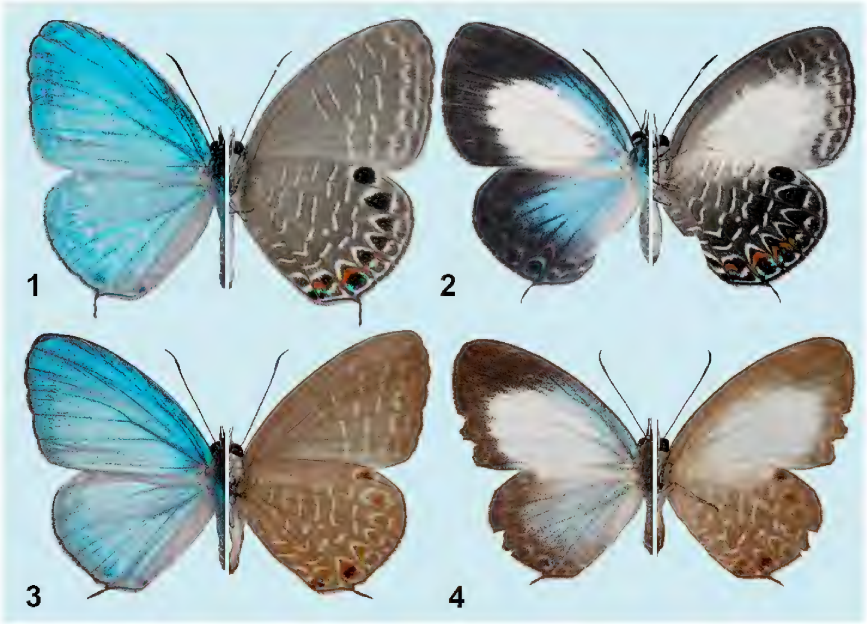
Observations and discussion

In January 2021 a male and female of a *Jamides* species were collected on separate days along a rainforest track on Dauan Island, Torres Strait, Queensland. The specimens matched the types of *J. c. amphissina*, illustrated in Müller (2016), from Humboldt Bay on the northern coast of Indonesian Papua. Several years prior to the collection of these two specimens I.R. Johnson (*pers. comm.*) reported the sighting on Dauan Island of what he believed to be a male *J. c. amphissina*. Thus, the collection of these two specimens confirm its presence on the island.

The female's flight was slow and fluttering in the understorey while that of the male was rapid as it flew in a sunlit glade. The two butterflies were flying in the same haunts where *Nacaduba cyanea manto* (Grose-Smith and Kirby, 1896) (Lycaenidae) flew; and bore an initial resemblance in flight to the latter. Wood (1987) discovered larvae of *J. c. claudia* at Iron Range, Queensland, feeding on seeds within the fruits of *Syzygium puberulum* Merr. and L.M. Perry (Myrtaceae). This may well be the host plant on Dauan Island as this species is known from evergreen notophyll vine forest on the island (Anonymous 2013).

The dominant vegetation types on Dauan Island are deciduous and semi-deciduous monsoon forests which grow extensively amongst granite boulders (Anonymous 2013), with semi-evergreen notophyll vine forest growing at higher elevations on Mt Cornwallis (Webb 1959; Anonymous 2013). All forest types constitute over 43% of the island with native grassland complexes making up the next largest area (around 21%) of vegetation on the island (Anonymous 2013), with the balance of the area composed of boulder fields or talus, and urban areas. Because of the steep boulder talus, tall grasses and dense vine forest, the bulk of the island's terrain is difficult to access.

Dauan Island may be considered a butterfly hotspot (high butterfly diversity), as current data indicate that 143 butterfly taxa (unpublished data) have been recorded from the island and this number continues to rise with successive sampling visits (Fig. 5). Ten of these taxa are only known in Australia territory from Dauan Island



Figs 1–4. *Jamides cyta.* All figures not to scale: upperside left, underside right [forewing lengths, in mm, in square brackets]. (1, 2) *J. c. amphissina*: (1) ♂, Dauan Is., Torres Strait, Qld, 18.i.2021 [19], (2) ♀, same data except 13.i.2021 [20]; (3, 4) *J. c. claudia*: (3) ♂, Iron Range, Qld, 9.viii.2001 [18], (4) ♀, 3rd crossing of Gordon Ck., Iron Range, Qld, 1.viii.2000 [14].

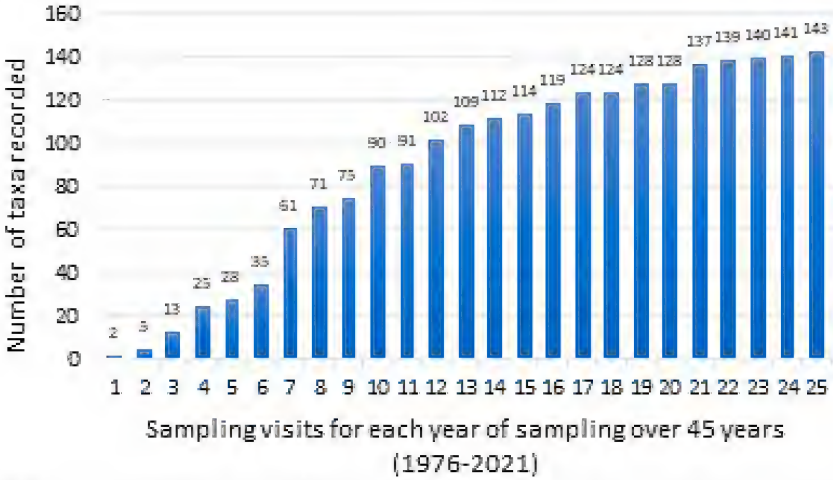


Fig. 5. Cumulative totals of butterfly taxa recorded from Dauan Island, Torres Strait since the first record in 1976 till January 2021 (the data is from 45 individual visits over 25 separate years; multiple visits made in the same year have been merged)

(Johnson and Wilson 2019). Equally, Moulds *et al.* (2020) indicated that Dauan Island has a high hawkmoth diversity.

While a proportion of the richness of the butterflies of the island may be attributed to vagrancy from nearby Papua New Guinea (Lambkin 2019) or dispersion (Meyer *et al.* 2015), there remains a high number of lycaenid species, especially the less vagile or more secretive, such as *J. c. amphissina*, that are more than likely resident on the island. So one may ask, how do these species, remain undetected for so long on the island, despite many visits by butterfly workers (45 visits, Fig. 5), mostly over the last two decades?

Of the 4.0km^2 surface area of Dauan, only a small proportion is easily accessible to sampling, calculated here at approximately 9% (using Digimizer 2020). Anonymous (2013) reported that there are six different vegetation communities of evergreen and semi-deciduous forest types on the island, with most of these plant communities in quite inaccessible areas where butterflies are not easy to sample. This suggests that, despite a significant sampling effort being undertaken on the island over the last several decades, the efficacy of this sampling is largely biased due to the degree of accessibility. This may explain why several butterfly taxa, particularly lycaenids that are likely resident, that have low vagility, have secretive habits or are forest canopy dwellers are only known from a relatively small number of specimens. This is perhaps why some taxa are still being newly discovered despite many years of sampling.

Acknowledgements

I thank the local community council and island elders of Dauan Island for allowing entry into their community. In particular, the island Councillor Torenzo Elisala, and the two island rangers, Laurie and Tenny Elisala. A review of the first draft of the manuscript by M.P. Zalucki (The University of Queensland) was greatly appreciated. I am appreciative of I.R. Johnson for his personal communication. This paper partially fulfils the requirements for a Master of Philosophy degree undertaken by the author at The University of Queensland, Brisbane.

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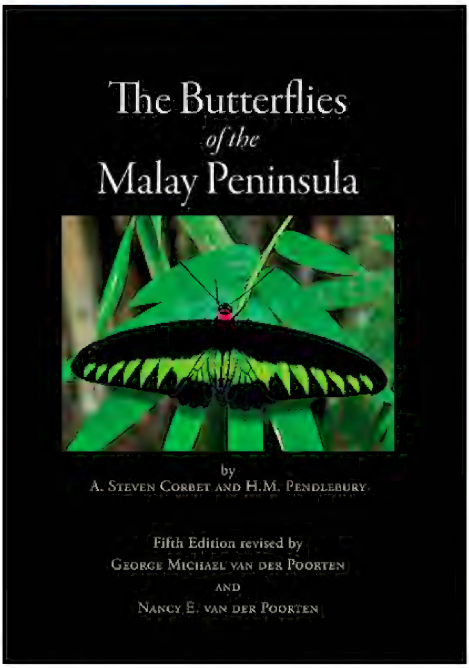
BOOK REVIEW

The Butterflies of the Malay Peninsula by A. Steven Corbet and H.M. Pendlebury. Fifth edition. Revised by George M. and Nancy E. van der Poorten. Southdene Sdn. Bhd. Kuala Lumpur, Malaysia. 2020; xiii + 492 pp, 138 colour plates. Price from the publisher (hsbar@hotmail.com or misssallylee@yahoo.com), $US60 plus postage and handling. See also (https://www.mothsofborneo.com/C&P5_flyer_medRes.pdf). ISBN: 978-983-44886-3-5 Hardback.



This is the fifth revision of the classic handbook, *The Butterflies of the Malay Peninsula* by A.S. Corbet and H.M. Pendlebury (C&P), first published in 1934.[1] In assessing the present volume, it is important to be aware of its antecedents, and understand how subsequent revisors have striven to retain much of the flavour and intent of the original volume while continually updating it as our knowledge increases, as well as adding to its usefulness as an identification guide.

The first edition of C&P was not the first significant book on Malaysian butterflies. In 1882–86 W.L. Distant published the large format *Rhophalocera Malayana* with 44 lavish chromolithograph plates of exceptional quality figuring the 503 known species. However even by 1934 this was well out of date, unwieldy and difficult to obtain.

The first edition of C&P added nearly 300 species to the known fauna, but was nevertheless very limited in its detailed species coverage. It had only two colour illustrations, (both oil paintings of birdwings), and a very selective treatment of species illustrated by black and white photographs. For example, of 63 species of '*Amblypodia*' (mainly=*Arhopala*) then known, just one was discussed and illustrated. Recalling his early days collecting in the 1930s, Col. John Eliot, in his preface to the third (1978) edition, states '*It was not comprehensive enough to enable me to identify many of the butterflies I was catching*'. In fact, the first edition did not aim at being an identification guide so much as an introduction to the science of Lepidopterology. It discusses collecting techniques, biology and genetics. Its checklist of 801 then known species includes cross references to

[1] See https://digitalgems.nus.edu.sg/shared/colls/blsea/files/ButCor.pdf

illustrations of almost all species in Adelbert Seitz's Indo-Australian Rhophalocera volume of Macrolepidoptera of the World. The English edition of this volume had appeared in 1927 and in 1934 it was still reasonable to expect it might be available in good libraries.

A second edition was delayed by the death of Steven Corbet in 1948, but it eventually appeared in 1956, with expanded species accounts and keys, and a species tally of 898. On my first collecting trip to Malaysia in 1974 I found it an essential reference but quite challenging to use, as identification was largely dependent on unillustrated keys. Then in 1978 the third edition revised by John Eliot appeared. This greatly improved volume included 35 plates, most of them in colour, and listed 1008 species. Because peninsular Malaysia and Borneo share almost 90% of their fauna this, and the later 1992 fourth edition also revised by John Eliot (with 69 plates, mainly in colour, and 1031 species), became key reference works for me in my butterfly research while living and working in Brunei during the 1990s. In particular both included extensive genitalia plates, redrawn and added to from the second edition, that were critical for resolving the identity of some of the more intransigent lycaenids and hesperiids.

So, what does this new revision bring? To begin with, its jacket is adorned with a perched, living male *Trogonoptera brookiana*, as opposed to the dead museum specimens that appeared on the second, third and fourth editions. This is a pleasing change in keeping with modern sensibilities, and dare I say it, my own. Also, the text is laid out at two columns per page, and subheadings are in bold, both features that enhance its readability compared with older editions. However, the changes are more than skin deep. Although the introductory chapters follow exactly the same arrangement as the fourth edition and swathes of Corbet's and Eliot's text are repeated verbatim, a close reading at once reveals many important additions and amendments.

To begin with, the revisors introduce the modern redefined family level phylogeny of the butterflies first presented by Heikkilä et al. (2011) and subsequently verified and refined by various authors. This completely overturns our traditional understanding of butterfly phylogeny and leads to a revamped account of the subdivisions of butterflies. Then throughout the introductory chapters there follow numerous small improvements: 'External anatomy' has a helpful new drawing clarifying the terminology of wing morphology; the chapter on distribution updates the species counts of butterflies according to their centre of origin and also discusses changes in weather patterns in the past 30 years, including recent as well as historical rainfall records for various localities; 'Butterfly populations' includes a discussion on the effects of *Wolbachia* bacteria and their potential effect on sex ratios; "A history of butterfly studies in the Malay Peninsula" adds recent significant collections that have been acquired by the Malaysian and Singaporean national museums, as well as noting important advances in our knowledge of ecology and life histories; "Making and studying the collection" includes two important changes—instructions are provided for preparing specimens suitable

for DNA analysis, and the formula given in earlier editions for protecting dried specimens from mould and pests is declared carcinogenic and alternatives are suggested. In short, the introductory chapters have been updated where necessary while preserving as much of the original as possible.

The second, and by far the larger part of the book is the systematic treatment of the fauna. Classification and nomenclature are substantially revised at every level. Two families, the Nymphalidae (11 versus 7 subfamilies) and Lycaenidae (7 versus 5 subfamilies) follow a different arrangement of subfamilies from that used in the fourth edition. For Nymphalidae a modern molecular phylogeny is also provided. At the generic and species level there are many widely accepted changes of status. Thus, *Pachliopta coon doubledayi* in the fourth edition is listed as *Losaria doubledayi*; *Graphium* and *Papilio* are treated as single genera (as opposed to *Graphium* + *Pathysa* and *Papilio* + *Chilasa* respectively in the fourth edition). These changes are based largely on recent molecular analysis and reflect a modern consensus; there are numerous other examples. The total number of species is now 1051, 20 more than in in the fourth edition. Keys to all taxa are provided and the extensive rearrangement in classification and addition of species means many of these too have had to be revised. In keeping with Eliot's keys a few Bornean and Sumatran species are also included. The species accounts are also revised to accommodate new hostplant and distribution records and this has been done well.

Throughout the text are numerous helpful line drawings showing details of wing venation, legs, labial palps and androconial scales. Most of these are copied directly from the previous editions and total 136 individual drawings in the species accounts of both the fourth and fifth editions. However, pen and ink style drawings (in some cases edited digitally) of 15 larvae and 14 pupae, showing examples from every family and some subfamilies, are redrawn with improved accuracy and clarity. Not only are the new drawings cleaner and more attractive; they are more lifelike. As an example, the larva of *Hebomoia glaucippe* in previous editions is clearly drawn from a 'blown' museum specimen. The new version is drawn from life, or at least from a photograph of a living larva. They are a great improvement.

The fourth edition included 455 drawings of genitalia, mainly male, representing all families, arranged in 25 separate plates with facing legends. These are well executed and are invaluable in identifying many lycaenids and hesperiids. The revised edition presents these in considerably more compact form and adds four species to the total. Otherwise, the plates are almost identical, with the exception of *Pieris canidia*, for which the non-descript female genitalia are replaced by male genitalia.

The main text is supplemented by no fewer than seven meticulously compiled, scholarly appendices. These are A: a full checklist with distribution codes within the area and cross references to illustrations in Fleming (1983), B–D: Notes on omitted species, questionable records and species new to the checklist and notes

on endemicity, E: Taxonomic and distribution notes, with nomenclatorial changes explained, F: Tabular census of species group taxa at the tribal level (with 61 tribes in total), and G: Larval foodplants of Malayan butterflies. Taken together the appendices provide an excellent summary and source of information which is at once highly accessible and avoids cluttering the main text.

The main text and appendices are supported by an extensive bibliography of over 1000 publications. Numerous references have been added since the fourth edition, and the considerable literature on molecular phylogeny that has appeared in the last 15 years is particularly well represented.

One entirely new feature that distinguishes this edition from its predecessors is the inclusion of six colour plates of immature stages, showing the egg, larva and pupa of five species per plate, or 30 species in total. While this is very welcome, I was a little disappointed not to see, for example, the striking brown and yellow larvae of *Delias pasithoe*, which bred on a mistletoe (*Dendrophthoe* sp.) in my garden in Brunei, or the unusual strings of eggs of *Papilio demolion*. If finances had permitted, at least 12 plates would have done more justice to the wonderful variety of forms and behaviours that occur among the early stages of Malaysian butterflies.

However, these minor misgivings are more than compensated by the new adult plates. The fourth edition included 69 plates of adult butterflies, mainly in colour. The present revision has 132 entirely new full colour plates, comprehensively illustrating the adult fauna. By using half wing illustrations, rather than entire specimens, the revisors have managed to show the upper and underside of both sexes of most species, thus providing far more information than the fourth edition. For the first time we have a comprehensive visual guide to the butterfly fauna of the Malay Peninsula.

Another slightly negative aspect of the book, and Eliot's revisions, is the missed opportunity to amend text carried over from the second edition. All revisors have apparently accorded the original authors undue deference. For example, the naïve, unaltered account of structural colour (p.5) ignores the vast strides in this subject that have been made in the past 25 years; among Malaysian species the mechanism of colour production by *Papilio palinuris* is the subject of at least three important papers (e.g. Vukusic *et al*. 2000). The subject has grown too vast and esoteric to receive more than passing mention in a book of this sort, but this situation could have been explained. Another surprising anomaly repeated in this revision, is the poorly substantiated claim that *Hypolimnas misippus* and *Danaus chrysippus* are Müllerian mimics (p. 31), whereas it is widely accepted that the former is a Batesian mimic of the latter (Smith, 1973, Gordon *et al*. 2010); indeed, the association is regarded as a classic example of Batesian mimicry and there is a wealth of evidence from across the species' vast areas of sympatry supporting this. It was also surprising to read of the genus *Delias* (p. 75): "The seventy odd species {worldwide}…". There are in fact a conservative 235 species currently recognised, more than a fifth of all Pieridae, and over 200 species were known

at the time of the second edition when this error was introduced, then copied uncritically into subsequent revisions. Given the degree of authority the book carries in the region it is important to avoid perpetuating such misconceptions.

Despite these few criticisms, which are mostly not specific to this revision, I consider that the revisors have done a magnificent job. Their task can not have been an easy one, especially given the need for the book to retain the essence of its predecessors. This they have achieved with skill. The plates alone represent a prodigious undertaking and are superbly executed, but one must also appreciate and admire the amount of work required to bring the text up to date. The wonderfully readable blend of elegant prose remains, but having consulted previous editions extensively, I can state categorically that this is by far the most user-friendly edition, and it retains its status as the definitive scientific authority on butterflies for the region. I strongly commend this book to all serious students of butterflies, even if you already possess the fourth edition. To enthusiasts residing in Malaysia, it is a 'must have'. The book retains the same crown quarto format of its previous editions and is a sizable and quite heavy tome, suitable for travel, but not intended for use in the field. That said, it travels well in the back seat of a car ready for rapid consultation while out collecting. The sorry state of my third edition is testament to this!

The revisors have informed me that since going to press they detected various corrigenda. These, plus recent addenda may be found at: http://www.lepodonbooks.com/corrigenda_C&P5.html

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Reviewed by Albert Orr

FROM SOUTH AFRICA TO TORRES STRAIT THE LIFE AND LEGACY OF ARTHUR IAN KNIGHT (1930–2021)

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Introduction

The early hours of Saturday 17 April saw the end of a special era in Australian butterfly collecting with the passing of Arthur Ian Knight (known to us simply as Ian Knight) in Deloraine, Tasmania. For those of you who knew Ian, he could only be considered a true 'English' gentleman among gentlemen. His passing is noteworthy in that he was the third Australian butterfly expert that the discipline has lost in the last decade, viz. Murdoch De Baar in 2011, Stephen J. Johnson in 2014 and now Ian Knight in 2021. I knew Ian since 1979, almost 42 years, and during that time we spent many a field trip collecting and learning together and as a result, his impression on me and the Australian butterfly world will remain. In this brief testimony of his life, I shall go back to his entomological origins in South Africa, through his retirement in Exton, Tasmania, to his final adventurous forays into Torres Strait, Queensland, including his lifetime of silent volunteering.

(Arthur) Ian Knight
19 January 1930–17 April 2021

The early years in South Africa

Ian was born on 19 January 1930 in Uitenhage, Eastern Cape, South Africa, a twin with sister Jeanne. Ian had an older sister, Sheila, who died in her 30's from a rare disease. The family grew up on a citrus farm ('Allanwater Farm') in Summerville, on the banks of the Sundays River, about '45 miles' east of Port Elizabeth, Eastern Cape, South Africa (Fig. 1). Ian's dad (Arthur Probart Knight) is renowned for his discovery of the 'MidKnight' Valencia orange variety (Anonymous 2021).

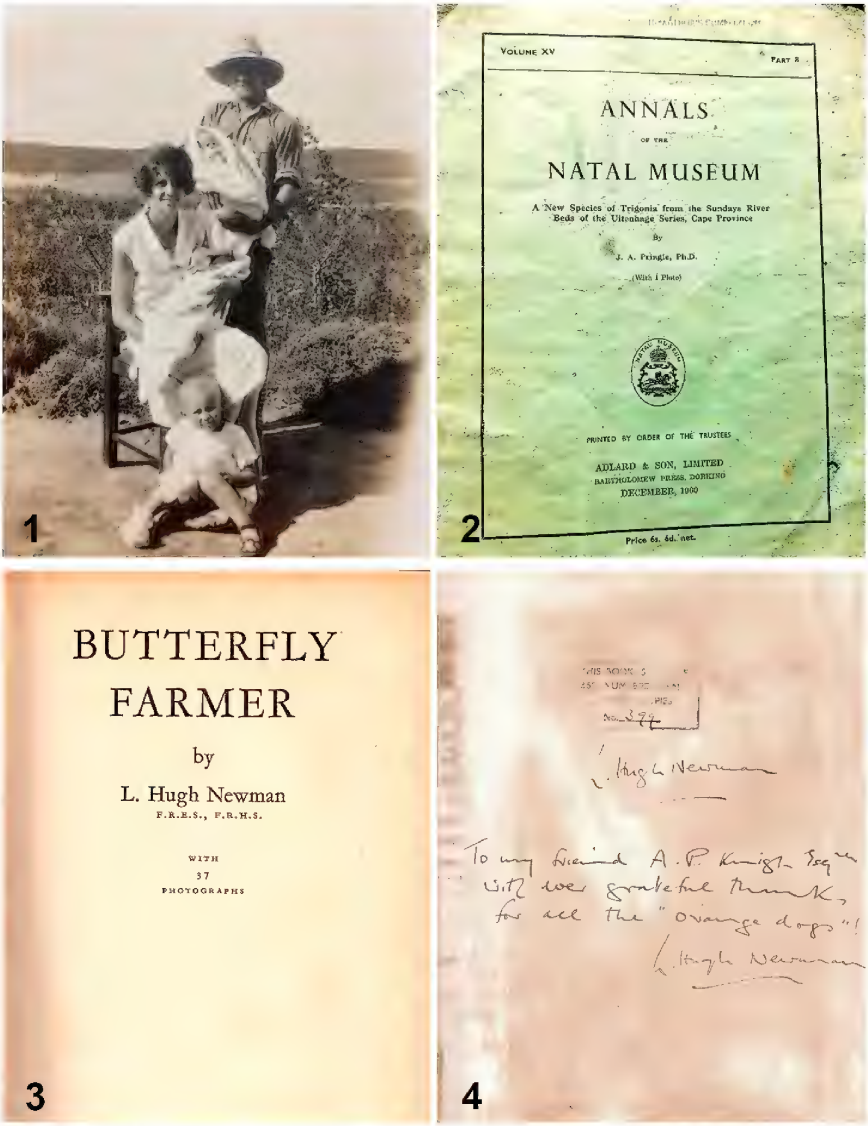
An interest in butterflies was not apparent at an early age but he always had an inherent love for nature and during his early adult years developed a keen interest in fossicking for fossils. He was a collector from the beginning, also searching for and collecting antique bottles. Interestingly, the banks of the Sundays River happened to be a well-known fossil bed site and Ian humorously told the story of, one day while fossicking, to gain a better view of the surrounding area, he stood on a high point on the fossil bed and while surveying the surrounding area, he happened to look down and realised that he was standing on a large fossil of a mature marine mollusc (*Trigonia* sp.). He subsequently was told that the fossil was a new species of *Trigonia* and, at the time, the largest known species within that genus. Following this, he found several other immature specimens of this new species and the species was aptly named *Trigonia knighti* (Pringle 1960) (Fig. 2). This holotype is now in the Port Elizabeth Museum.

Ian was accepted into University of Cape Town with a scholarship ('Cape of Colours') for his woodworking skills and graduated first in his year in architecture. Additionally, he was a surf lifesaver in his younger years, even owning a Malibu surfboard. He was a renowned and accomplished architect in Port Elizabeth.

Fossils were not his only link to nature, as during his younger years on the citrus farm he learnt from his father how to rear several species of citrus feeding *Papilio* butterflies that were common on the citrus farm. This was just after World War II and Ian's father had answered an advertisement in the newspaper asking for livestock of *Papilio* pupae from South Africa. The advertisement was from none other than L. Hugh Newman from England who ran the world's first butterfly farm at Old Bexley, Kent. Hugh's father, Leonard Woods Newman commenced the farm in 1894 and the business ran over two generations well into the 1950s. The butterfly farm was associated with well-known figures such as Lord Rothschild and Winston Churchill. Thus, in the 1940's Hugh Newman was seeking more exotic material and South Africa must have been a likely source. Ian was exposed at that relatively young age to producing large quantities of butterfly stock for the world's most famous butterfly breeder (Fig. 3). During that period Ian was well familiarised with the butterflies and moths of England through Newman's publications (*Butterfly Haunts* (1948) and *British Moths and their Haunts* (1950)) (Fig. 4).

The late fifties saw Ian meet Cynthia (Cindy) Harvey who was a radiographer from England working abroad in South Africa, which was a frequently done thing in those days. Cindy had begun the start of her world trip in March 1960 at Port Elizabeth, South Africa, met Ian and the trip never continued. They were engaged in South Africa and they then travelled to Cindy's English homeland and were married in North Thoresby, Lincolnshire, England on 3 January 1961 (Fig. 5). They were married for just over 60 years.

It took another nine years, till the early 1970's for Ian to rekindle his interest in nature, resulting in a deep passion for butterflies. He was inspired by some of the great South African collectors of the time including D.A. Swanepoel,



Figs 1–4. (1) The Knight family soon after the birth of the twins (1930); (2) A new species of *Trigonia* (*T. knighti*) from the Sundays River Beds (1960) (With the author's compliments); (3) *Butterfly Farmer*, L. Hugh Newman (1951), The Scientific Book Club, London; (4) *Butterfly Haunts*, L. Hugh Newman (1948), Chapman and Hall, London, with inscription: "To my friend A.P. Knight Esquire with our grateful thanks for all the 'orange dogs'! L. Hugh Newman". 'Orange dog' is the colloquial name given to the larva of *Papilio demodocus* (citrus swallowtail) in South Africa. It is thought that the osmeterium of the larva gave rise to the term 'Orange dog'.

Fig. 5. Cindy and Ian around the date of their wedding (1961).

Ken Beetlestone, S.F. and G.A. Henning, and Jonathan Ball (Anonymous 2017). During this relatively short period Ian collected over 400 of the 660 species known to occur in South Africa. Over this decade of the 1970's Ian and Cindy had three children, Adrian, Bruce and Frances. This period was an uncertain time in South Africa due to the political unrest in the country and Ian decided that it was not the safest environment to raise his family. Consequently, Ian, Cindy and family emigrated from Port Elizabeth to Australia in 1978. He later donated the bulk of his South African collection (in the late 1990's), which he brought to Australia, to what was then the Queensland Department of Primary Industries insect collection at Indooroopilly, Brisbane (now Department of Agriculture and Fisheries, Queensland).

Time in Brisbane

Ian and family took residence in St Lucia where he worked in Brisbane as an architect and Cindy as a radiographer. Commencing in 1979, he collected butterflies in the local St Lucia area and then ventured out to collect along the D'Aguilar Range up to Mt Nebo. Later in 1979, he had an unlikely encounter with Geoff Monteith who passed on his invitation to Ian to attend a butterfly enthusiast's meeting to be held in September of that year at the newly opened Griffith University at Nathan. From memory, at the meeting were Don Sands, Murdoch De Baar and Steve Johnson, and it was at this meeting where I met Ian and that started a friendship that lasted over four decades. Ian was quick to take up the challenge of collecting Australian butterflies, and being only a beginner myself, we decided to team up and collect together, often joining in with other contemporary Brisbane collectors such as De Baar, Sands and Kerrod Beattie.

Ian first collected in the Wet Tropics in 1982, followed by our first visit to Thursday (Waiben) and Prince of Wales (Muralug) Islands, and Bamaga in 1983 (Lambkin and Knight 1983). Over the next decade or so Ian collected widely in southern Queensland, Darwin, New South Wales, ACT, Victoria and Tasmania, including a trip to Iron Range and doing a return trip to Bamaga. How quickly he moved through these areas, building up such an extensive collection in such a short time was a testament to his energy levels, enthusiasm and passion. He

Fig. 6. Ian on Dauan Island chasing *Graphium codrus* (2012)

was a true explorer never shirking from a challenge, particularly if it required venturing into a remote location. To name just a couple of highlights during this period, in 1992 he discovered the new *Ocybadistes knightorum* Lambkin and Donaldson, south of Coffs Harbour, NSW, and on a cold October day in 1996, he rediscovered *Herimosa albovenata alboventa* (Waterhouse) just south of Bredbo, NSW.

Retirement in Tasmania

In 1995, Ian retired from his architectural job, which meant that he had more time now to pursue his butterfly interests. Just prior to retirement he and Cindy indicated that they had an ambition to spend their remaining years travelling around Australia, collecting butterflies as they travelled. Their starting point was Tasmania, but on settling into life in the Meander Valley near Deloraine, they quickly realised that Tasmania was where they wanted to stay. Thus, in the late 1990s, Ian and Cindy settled in Tasmania, Ian donating the bulk of his collection to the Queensland Museum, and quickly he became the local expert in all things butterfly in Tasmania. During his time in Tasmania, he collected right across the island and was one of the few people to collect butterflies on Flinders and King Islands in Bass Strait. Ian was always cynical of the number of subspecific names that existed for butterfly populations in Tasmania. He always pronounced that he could collect pupae of all the Tasmanian races of the Silky Hairstreak, *Pseudalmenus chlorinda* (Blanchard) on one eucalypt tree.

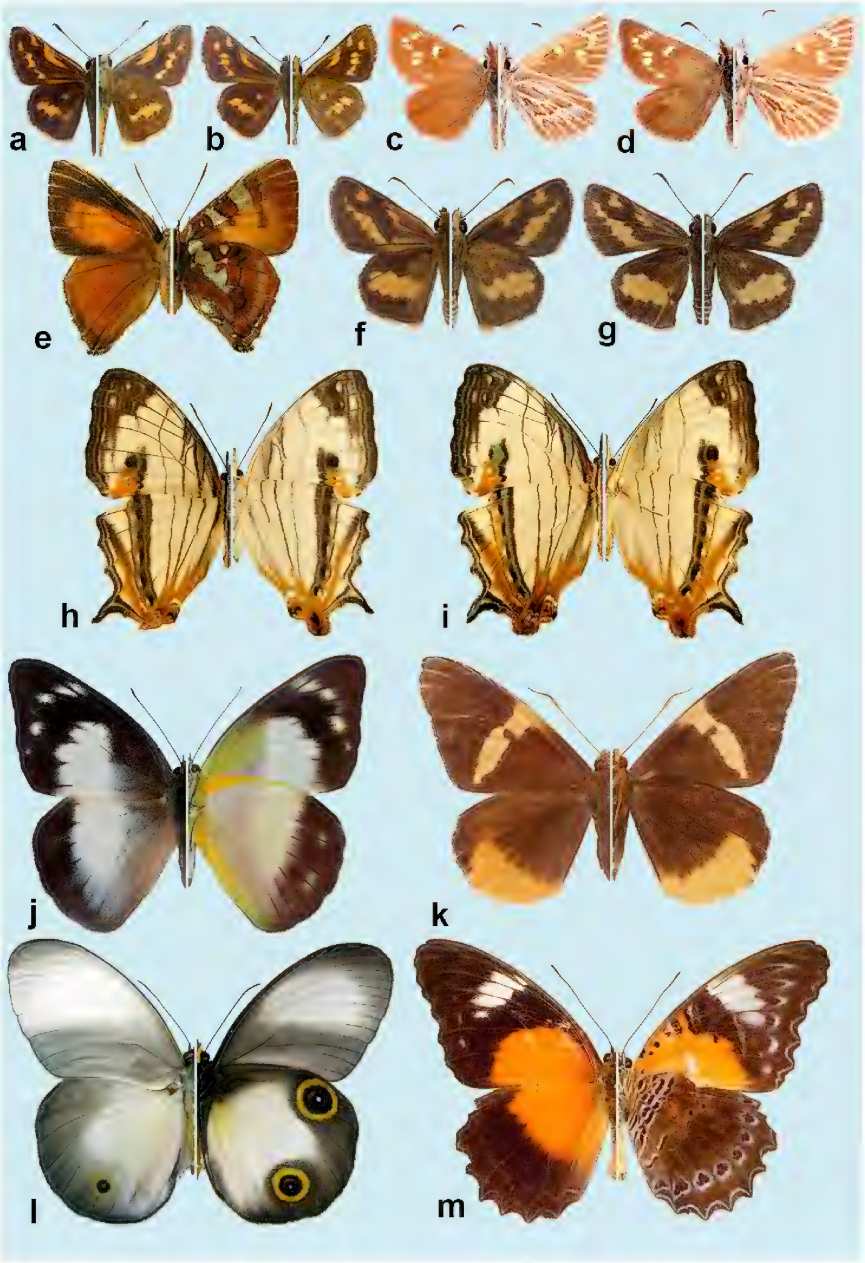


Fig. 7. Some of the Australian butterflies that were special to Ian (full details of each specimen are outlined in Table1).

Fig. 8. Ian's last trip to Torres Strait was when we collected on Mer Island in January 2016.

The Torres Strait years

Arguably Ian's most significant contribution to the study of Australian butterflies was his comprehensive butterfly collecting on the islands of Torres Strait. His initial collecting trip to Thursday Island in 1983 sparked an avid interest in island butterflies. After this, he made a subsequent trip to Murray (Mer) Island in 1986, and Murray again in 1989 together with Thursday, Hammond (Keriri) and Horn (Ngurapai) Islands (Lambkin and Knight 1990). In 1992, Ian and I were the first and only collectors thus far to visit Boigu Island, and we also collected on Saibai, Dauan and Thursday the same year. In the 1990's and early 2000's Ian visited Yam (Iama), Darnley (Erub), Murray, Dauan, Saibai, Moa, Thursday and Horn Islands (many several times over). Over this period, he made many visits to Thursday Island where he stayed at the Federal Hotel on Victoria Parade. Much to the objection of the locals he was the unchallenged snooker champion in the front bar of the hotel, the same bar where the Mills Sisters sang regularly. Breaking tradition, in 2003 he made a trip to Christmas Island, the second butterfly collector to visit the island, and in 2006 he collected butterflies on Norfolk Island.

Commencing in 2000, he comprehensively collected on Mer, Saibai and Dauan Islands, staying on some islands for quite lengthy periods (Fig. 6). Over this period on some trips, he collected alongside some of the new breed of Torres Strait butterfly collectors, such as Cliff Meyer, Steve Brown and Richard Weir, and the

Table 1. Australian butterfly species that were special to Ian (specimens are illustrated in Fig. 7), with several unique Australian specimens from Torres Strait resulting from his collecting efforts.

Letter	Species	Specimen data	Distinctiveness	Reference in literature
a, b	*Ocybadistes knightorum* Lambkin & Donaldson, 1994 ♂, ♀	Boambee Ck. S of Coffs Harbour, NSW, 29.ix.1994, AI Knight	Discovered by Ian & Cindy Knight in 1992	Lambkin and Donaldson 1994
c, d	*Herimosa albovenata albovenata* (Waterhouse, 1940) ♂, ♀	Rest area, 13km W of Bredbo, NSW, 28.x.1986, AI Knight	Rediscovered by Ian Knight in 1986	Braby 2000
e	*Hypochrysops chrysargyrus* Grose-Smith & Kirby, 1895 ♀	Saibai Is. Torres Strait, Qld, 11.ii.2004, AI Knight	The only specimen known from an Australian territory	Lambkin and Knight 2005
f, g	*Arrhenes marnas marnas* (C. Felder, 1860) ♂, ♀	♂ Dauan Is. 11.v.2001, Torres Strait, AI Knight ♀ Saibai Is. 22.iv.2001, AI Knight	The only specimens known from an Australian territory	*The butterflies of the Torres Strait islands: a fauna in review*. Thesis submitted by T.A. Lambkin to The University of Queensland for a Master of Philosophy degree
h, i	*Cyrestis achates nedymmus* C. & R. Felder, 1865 ♂, ♀	♂, ♀ Dauan Is. 18.i.2004, AI Knight	The first two collected of less than a handful known from an Australian territory	Lambkin and Knight 2005
j	*Appias celestina* (Boisduval, 1832) ♀	Dauan Is. 14.i.2004, AI Knight	The only specimen known from Torres Strait	*The butterflies of the Torres Strait islands: a fauna in review*. Thesis submitted by T.A. Lambkin to The University of Queensland for a Master of Philosophy degree
k	*Chaetocneme critomedia sphinterifera* (Fruhstorfer, 1910) ♀	Saibai, 19.iv.2001, AI Knight	The only specimen known from Torres Strait	*The butterflies of the Torres Strait islands: a fauna in review*. Thesis submitted by T.A. Lambkin to The University of Queensland for a Master of Philosophy degree
l	*Taenaris myops kirschi* Staudinger, 1887 ♂	Dauan Is. 24.ii.2006, AI Knight	One of four males known from an Australian territory (all collected by Ian)	Lambkin 2010
m	*Cethosia cydippe damasippe* C. & R. Felder, 1867 ♂	Saibai Is. 3.v.2000 AI Knight	The first specimen collected of only a pair known from an Australian territory	Lambkin and Johnson 2015

Fig. 9. Ian busy curating his collection in the Queen Victoria Museum and Art Gallery, Launceston (2020)

photographer Geoff Walker. He also rubbed shoulders with some of the Torres Strait old timers, such as Grant Miller and Murdoch De Baar. I accompanied him on almost all his Torres Strait trips. The most extended period he stayed was on Dauan Island from December 2005 through to March 2006, during which he spent two weeks collecting on Saibai Island. Because of his extended stays on Dauan Island, Grant Miller once jokingly commented that Ian could stand as a candidate for the local council elections on Dauan as he could almost be considered a local on the island. Thus, during the first decade of the 2000's, he collected several species from Torres Strait that have only been recorded by Ian and several others that are known from only a few specimens including Ian's specimens (Fig. 7) (Table 1). For the description of *Hypolycaena litoralis* Lambkin *et al.* (2005) in Torres Strait, Ian collected 47 of the paratypes used for the description. In addition, he collected larger series of previously, poorly known Torres Strait island taxa that provided clarification of their taxonomy, residency and distribution, e.g. *Euploea alcathoe misenus* Miskin (Lambkin 2005, Lambkin *et al.* 2019), *E. resarta* Butler (Lambkin 2013), *E. netscheri erana* (Fruhstorfer) (Lambkin and Knight 2007), *E. leucostictos* (Gmelin) (Lambkin and Knight 2007), *E. tulliolus dudgeonis* (Grose-Smith) (Lambkin and Knight 2007), *Arhopala philander gander* (Evans) (Lambkin and Knight), *Taenaris artemis jamesi* Butler (Lambkin 2010), *Orsotriaena medus licium* Fruhstorfer (Lambkin 2008). His last

Fig. 10. Ian the adventurer in a poorly explored area on the eastern saddle of Dauan Island (2010)..

collecting trip in Torres Strait was on Mer Island in 2016, just five years ago (Fig. 8). The remainder of Ian's collection, along with the T.A. Lambkin collection, has been donated in part already to the Queen Victoria Museum and Art Gallery, Launceston (Fig. 9), and the remainder of the collection is also bequeathed to the same.

Ian the silent volunteer

Ian was a very covert volunteer, working away at gratis projects that few knew about, while never hinting about them. In South Africa, Ian assisted friends with interior decorating for many years and even had a football field named after him, the 'Knight Field', at Woodridge College, Thornhill where he had been a dedicated pupil and later freely contributed with the architectural design for the high school. In Brisbane, he designed the renovations for the local Anglican Church at St Lucia and contributed significantly to friends and family in all things architectural. After retirement in Tasmania, Ian and Cindy delivered 'Meals on Wheels', and Ian supervised the annual Craft Fair at Deloraine for 15 years and did design work for renovations to the Ashgrove Cheese complex in the Meander Valley to name a few. He presented butterfly talks to local schools and on radio and was an active member of Rotary and was awarded the Paul Harris Fellow Award and has the 'Ian Knight' meeting room named after him. In his later years, he assembled a collection of Meander Valley insects, around a thousand specimens, for a resident

Fig. 11. At the end of a collecting day on Dauan Island, discussing the days to come (2008).

of Chudleigh. All specimens were meticulously set of course.

In summary, Ian's time in Australia, particularly in Torres Strait, will remain an important legacy for the study of Australian butterflies, as now, in this new millennium, we are seeing a gradual decline in the number of serious and adventurous butterfly collectors (Fig. 10). It is this group of butterfly workers, of which Ian was one, that we owe so much for our overall knowledge of Australian butterflies. This tenacious quest for knowledge by this group (Fig. 11) has now hopefully resulted in the successful shaping of future conservation strategies for this special group of insects. Thus science owes a great deal to the Ian Knights of this world.

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Volume 48, Part 2, 30 June 2021

EMERY, N.J. and EMERY, D.L.
A new cicada species, *Haemopsalta eximia* (Hemiptera: Cicadidae) from north-western Sydney, Australia. 97

HUMPHREY, M.
Observations on the natural history of the platform-weaving spiders, genus *Corasoides* Butler (Araneae: Desidae). 75

LAMBKIN, T.A.
The first Australian record of *Jamides cyta amphissina* (Grose-Smith, 1894) (Lepidoptera: Lycaenidae) from Dauan Island, Torres Strait, Queensland with a brief analysis of the efficacy of butterfly sampling on the island. 109

LAMBKIN, T.A.
From South Africa to Torres Strait. The life and legacy of Arthur Ian Knight (1930–2021). 119

SHAKESPEARE, T.P.
First record of *Acraea terpsicore* (Linnaeus, 1758) (Lepidoptera: Nymphalidae) from New South Wales, Australia. 73

BOOK REVIEW
The Butterflies of the Malay Peninsula by A. Steven Corbet and H.M. Pendlebury. Fifth edition. Revised by George M. and Nancy E. van der Poorten. 114

RECENT LIERATURE 131

ISSN 1320 6133